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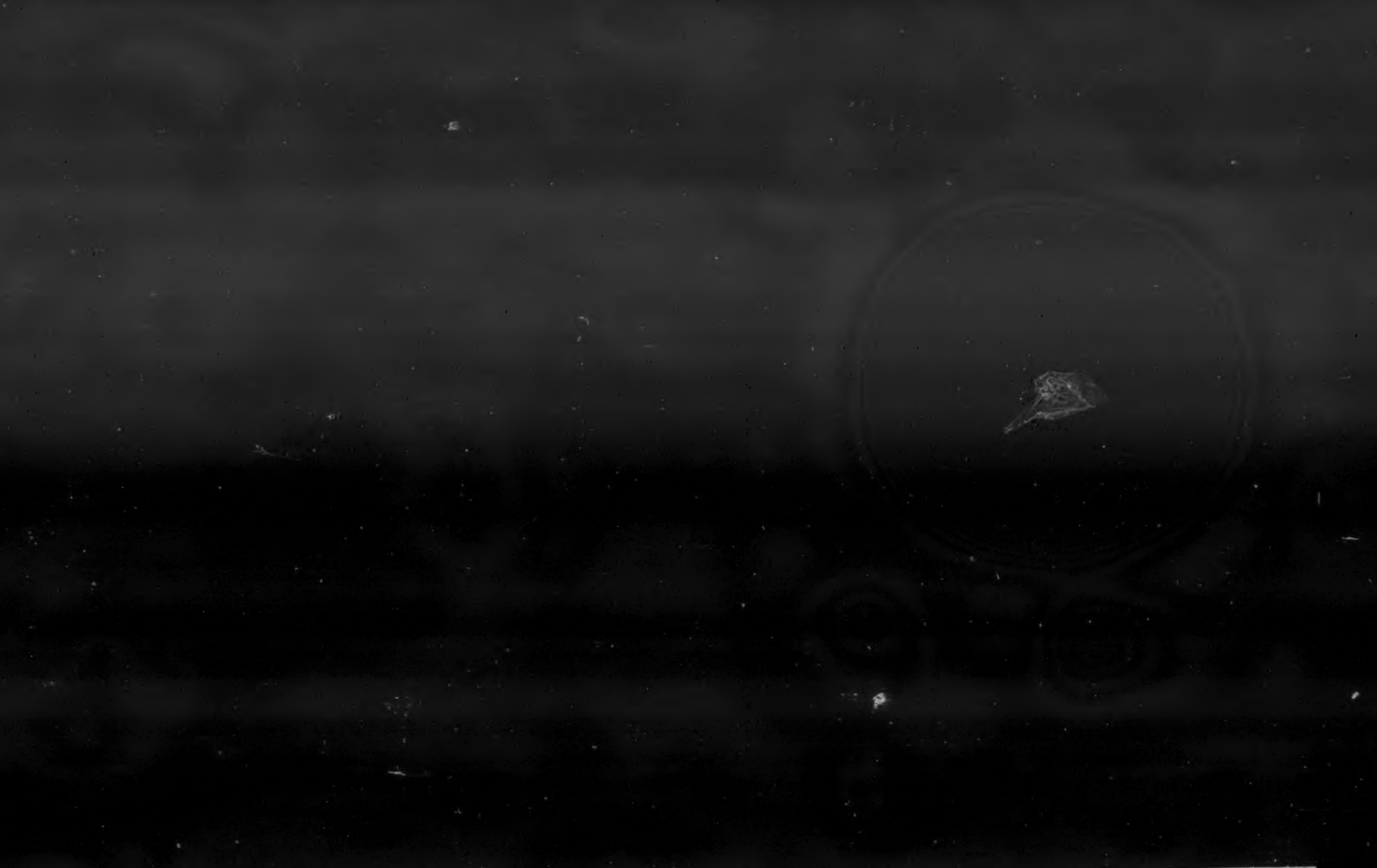


THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XVII.—*Recent and Fossil Tapirs;* by J. B. Hatcher. (With Plates II–V.)

[This investigation was aided by a grant from the Elizabeth Thompson Fund of the A. A. A. S.]

The existing *Tapirs* present many characters of peculiar interest, and in some respects, as for example, geographical distribution and conservativeness in accomplishing anatomical changes, they are unique among living Perissodactyls. Remains of fossil Tapirs and closely allied forms, though comparatively rare, have been found in Tertiary deposits belonging to nearly every period, from the Wahsatch, of the lower Eocene, up to, and including, the Quaternary, and in widely separated localities.

It is the purpose of this article to describe a new species of *Protapirus* from the *Protoceras beds* of the White River (*Oligocene*) of S. Dakota; and to add something to our knowledge of the osteology of this genus, especially in regard to the skull and fore limb; to give some additional characters diagnostic of the various species of *Protapirus* and *Colodon* already described by Leidy, Marsh, Wortman, Earle and Osborn; to point out distinctive osteological and dental characters in the skulls of the five generally accepted species of recent *Tapirs;* and to review previous work of others on the phylogeny of the *Tapiridæ* and *Helaletidæ*.

Protapirus (Filhol).

Wortman and Earle* have recently described, from the Oligocene of S. Dakota, remains of two species of *Tapiroids*,

*See Bull. Am. Mus. Nat. Hist., vol. v, pp. 159–180.

at present not distinguishable from the genus *Protapirus*, described by Filhol from the *Phosphorites du Quercy*, France. The species described by these authors are *P. obliquidens*, based on a nearly complete superior dentition (*No.* 659 *Am. Mus. Col.*). The authors do not give the horizon in which it was found, but from the matrix enclosing it I am led to believe that it is from the *Protoceras beds*. The other species is *P. simplex*, based upon a series of superior premolars and fragments of the lower jaw (*No.* 660 *Am. Mus. Coll.*) found in the *Oreodon beds*.

The Princeton Scientific Expedition of 1894 was fortunate in securing material, representing a third American species of this genus, besides other material which will increase our knowledge of the known species of *Protapirus* and the somewhat similar genus *Colodon*.

The following is given as a key to the *American* species of *Protapirus*.

1. Internal cone of all the superior premolars absolutely simple, showing no signs of division, with very rudimentary posterior cross-crests, especially in pms. 3 and 4....*P. simplex.*
2. Internal cone of the fourth superior premolar just commencing to divide, posterior cross-crests moderately developed on all of the last three superior premolars.....*P. validus.*
3. Internal cones of last two superior premolars commencing to divide, posterior cross-crests of the last three superior premolars like intermediate tubercles.....*P. obliquidens.*

Protapirus validus, sp. nov.

The type of the present species (*No.* 10899 *Princ. Coll.*) consists of a nearly complete skull, without the lower jaw and a complete atlas, humerus, radius, ulna and parts of other bones. It is from the *Protoceras sandstones*, about four miles south of White river and five miles below the mouth of Porcupine creek in S. Dakota; about one mile from the spot where the type of *Protoceras celer* was secured. It was found by Mr. H. F. Wells of Sturgis, S. Dakota, a most energetic collector of vertebrate fossils, who was the first to distinguish the *Protoceras beds* and the rich vertebrate fauna contained in them. These beds were shown by Mr. Wells to Dr. J. L. Wortman, who was the first to name and describe them.*

In most of the more important characters, *Protapirus validus* is intermediate between *P. simplex* and *P. obliquidens*, as for example, the structure of the internal cone of the sup. pms., but in some respects, notably, the development of the posterior cross-crests of these teeth, it is in advance

*See Am. Mus. Bull., vol. v, pp. 95–105.

of both of these species. (Compare fig. 3, plate II, of the present paper with A. & B., fig. 1, of Wortman and Earle.) From these and other characters *P. simplex* appears to have been the ancestor of *P. validus* and *P. obliquidens*. There seems to be little doubt that the former is a direct successor of *P. simplex*, while the latter has been derived from that species either directly through *P. validus* or some other as yet unknown form with all its characters intermediate.

The Skull: In many respects the skull of *Protapirus* resembles that of the recent Tapir, especially of *Tapirus roulini*, the least specialized of all the species of modern Tapirs. In the type specimen of *P. validus* the occipital condyles are sessile and as deep as broad. The condylar foramen is placed well forward and inward just opposite the base of the paroccipital process, which is a slender, styliform bone directed straight downward much as in *Tapirus roulini*, but quite different from *T. indicus*, in which species this process is broad and flat with its distal end curving inward. The post-tympanic process is low and broad and is confluent but not coössified with the paroccipital process; its lower extremity is curved forward, abutting against the post-glenoid and entirely enclosing the *meatus auditorius externus*, a condition not present in any of the living Tapirs. The post-glenoid process is low, broad and thin, and curves forward inferiorly; it is set obliquely to the longer axis of the skull, at an angle of about 45 degrees, much as in all the species of recent Tapirs. The zygoma is slender, only slightly expanded, and nearly parallel with the longer axis of the skull. There is no post-orbital process on the malar. The floor of the orbit is much deeper than in *Tapirus*, but not quite so deep as in some specimens of *Elasmognathus*. The infraorbital foramen is situated well in front of the orbit, and directly above pm. 4, at the bottom of a deep groove, which commences just above pm. 2 and runs obliquely backward and upward, from this point, until reaching the fronto-maxillary suture, where it turns abruptly backward and terminates at the post-orbital process of the frontal. This groove is, perhaps, homologous with a similar excavation on the surface of the skulls of modern species of Tapir. In recent Tapirs it is deepest at, or near, the base of the nasals, and its function, as has been shown by Parker,* is the lodgment of a cartilaginous air sinus; it very likely served the same purpose in *Protapirus;* the apparent and actual change in its position having been accomplished by the shifting of the nasals to a more posterior position in recent forms. The greatest depth of this groove, in *Protapirus*, is at a point just opposite the

*See: Some Points in the Anatomy of the Indian Tapir, by W. N. Parker, P. Z. S., 1882, pp. 768–777.

base of the nasals, where it attains a depth of 8mm, and a width at the top of 12mm. The premaxillaries in the present specimen are broken off at the base of the canines; they were strong, and had an extended contact with the maxillaries.

The most striking differences between the skull of *Protapirus* and that of the recent Tapirs are to be seen in the conformation of the superior aspect of the skull, and in the position of the frontals and nasals, relative to the other elements of the skull. In *Protapirus* the top of the skull, from the tip of the nasals to the occipital crest, is a nearly straight line, while in most recent Tapirs it is somewhat convex, and in *T. terrestris* (*Americanus*) it is strongly convex, especially in the region of the parietals and frontals. In the characters just mentioned *T. roulini*, among modern Tapirs, is most like *Protapirus*. In recent Tapirs the nasals occupy a position considerably posterior to that of the nasals in *Protapirus*, in which the posterior border of the nasal opening is directly above the anterior border of the orbit; while in recent Tapirs it is always back of the posterior constriction of the orbit.

The nasals are slightly injured in the present specimen, and it is impossible to determine their exact length, they could hardly have reached much in front of the posterior border of the premaxillaries; they are applied closely to each other, but are not coössified. They are narrow, deep, and triangular in cross-section anteriorly, but gradually expand and present a greatly thickened lateral edge, posteriorly. On the upper surface, and a little in front of the middle of the nasals, there is a ridge, running from the inner margin obliquely forward to the outer, and giving to these bones a peculiar twisted appearance. The frontals are low and broad, with distinct postorbital processes; from which temporal ridges extend obliquely backward and inward and unite to form a low, sharp, sagittal crest. The lateral edges of the frontals, above the orbits, are thickened and bent upward so as to form the external wall of the groove above described. The fronto-parietal suture marks the point of greatest constriction in the temporal fossa. The parietals are moderately expanded, and unite superiorly in a low, sharp, sagittal crest; which becomes broader in the region of the supra-occipitals, and gradually expands into the occipital crest, which is deeply emarginate, and considerably overhangs the occipital condyles. The combined length of the parietals and frontals in *Protapirus* is considerably greater than that of the same bones in *Tapirus indicus* or *Elasmognathus bairdii*, the two largest species of recent Tapirs, notwithstanding that skulls of either of the latter are fully two-thirds longer than the skull of *Protapirus;* from this comparison the remarkable reduction of the length of those bones, in modern Tapirs, becomes apparent.

In *Protapirus*, the anterior border of the posterior nares is opposite the middle of m. 2. The pterygoids are slightly bifid and rather strong. The *post-glenoid foramen*, *foramen lacerum medium* and *foramen lacerum posterius* are confluent, much as in recent Tapirs. The petrosal is deeply inserted. The tympanic is not present in our specimen; it probably was of the nature of that element in recent Tapirs, in which, according to Parker,* it is small, and does not become ankylosed to the surrounding bones, so that it is usually lost in the process of maceration, and rarely seen in dry skulls. I have never seen it, although I have examined about fifty skulls. The foramen ovale is in the alisphenoid, at the base of the pterygoid.

The teeth: The incisors are wanting and only the roots of the canines are present; they indicate that this tooth was rather small. The crown of pm. 1 is gone from both sides, and the roots indicate that there was a considerable individual variation in the size of this tooth. In the present specimen, the one on the left side was much the larger, and was fixed in the jaw by two roots; while that on the right was quite small, and had only one root. The succeeding superior premolars gradually increase in size, from before backwards; they all have external, and anterior and posterior basal cingula, and anterior and posterior cross-crests. The internal cone of pm. 4 shows a shallow, median groove, on its inner surface; an indication of division, which is absent in pms. 2 and 3. The posterior cross-crest in pms. 2 and 3 is rather better developed than in pm. 4. The latter tooth has a somewhat prominent parastyle, and its postero-external cone is situated a trifle farther in than the antero-external. Molar 1 is very much worn and its characters, consequently, not well defined; there is a pronounced basal cingulum, and the postero-external cone is situated farther in than the same element in pm. 4. In ms. 2 and 3, which are both well preserved, and scarcely at all worn, the antero-external cone is much larger than the postero-external, and the latter is placed far in from the former. The parastyle is nearly as high as the antero-external cone, and is continuous with the anterior basal cingulum. The anterior cross-crest is much larger than the posterior, and is united with the antero-external cone and not with the parastyle. Both of the external cones are convex externally. There is a deep median sinus which opens internally, but is closed externally. At the head of the median sinus there is a buttress. For an illustration of the more important characters of the skull and sup. dentition see figs. 1, 2, 3, plate II.

The lower jaw: No lower jaw was found with the type specimen, but a lower jaw (*No.* 10,900 *Princ. Coll.*), found in

* P. Z. S. 1882, p. 776.

the same locality and the same horizon, agrees perfectly, in size, with the type, and I have referred it to the same species, and made it a collateral type, figuring it in position in fig. 1, plate II. The inferior border is gently convex, the angle is slightly deflected, and its border turned inward, as in recent Tapirs. The mental foramen is a little in front of pm. 2. The symphysis is long and much constricted, as in *Tapirus*.

The teeth: Incisors 1 and 2 are of about equal size and much larger than I. 3, which is quite small, they are all spatulate and slightly cupped. The canine is small, conical and placed close to I. 3. The number of the inferior premolars is reduced to three. There is a long diastema between the canine and pm. 2. All of the pms. have two anterior cones, united by cross-crests notched in the middle; these cross crests are better developed in pms. 2 and 3 than in pm. 4, as has been shown to be the case in the posterior cross-crests of the sup. pms. The antero-external cone is situated farther forward than the antero-internal. There are also two posterior cones, but no posterior cross-crest; the postero-internal is the smaller and there is a low ridge running obliquely forward and inward from the postero-external cone and uniting with the base of the cross-crest. In addition to the elements already described there is a fifth cusp on the anterior border of pm. 2. The true molars each have two anterior and two posterior cones connected by high, sharp cross-crests. There are anterior and posterior basal cingula on all the inf. molars and premolars, but no external or internal cingula. The principal characters of the inf. dentition are well shown in fig. 4, plate II.

The Atlas: The articular surfaces for the occipital condyles are deep; those for the axis are of only moderate extent and curve inward exteriorly. There is a short dorsal spine, and a small posterior protuberance on the inferior arch. The transverse processes are only moderately expanded laterally, and posteriorly they extend but little beyond the articular surfaces for the axis. There is a vertebrarterial canal, and foramina, for the inferior and superior branches of the first spinal nerve. The present specimen agrees in every essential character with the atlas of *Elasmognathus bairdii.**

The fore limb: The humerus is proportionately rather strong and does not differ materially from that bone in recent Tapirs. The head is broad and sub-triangular in cross-section; the articular surface is continued upon the inner surface of the greater tuberosity, which is much larger than the lesser, and is produced, anteriorily, into an obtuse point which overhangs the bicipital groove. The deltoid ridge is prominent,

* An atlas of *E. bairdii* in the Princ. Coll. has the vertebrarterial canal present on one side and absent on the other.

and without the hook seen in recent Tapirs. The supinator ridge is rather more prominent than in recent Tapirs. The internal condyle is broader and stronger than the external. The anconeal fossa is deep and the supratrochlear shallow: there is no intercondylar foramen. The axis of the trochlea is at nearly right angles to that of the shaft. The intercondylar ridge is prominent and situated well outward, the ulnar articulation being much larger than the radial.

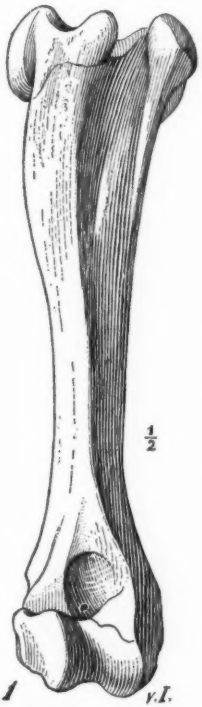


FIG. 1. Humerus of *Protapirus validus.*

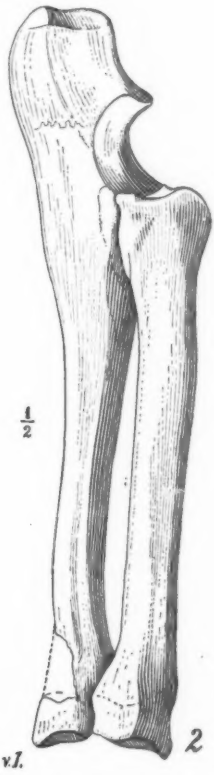


FIG. 2. Radius and ulna of *Protapirus validus*

The radius and ulna are proportionally rather more slender than the humerus. The olecranon is not pointed superiorly as in *Elasmognathus*, but is of nearly equal breadth from top to bottom. The proximal articulations of the radius and ulna bear about the same relations to each other, and to the

humerus as those of *Elasmognathus*. Our material does not enable me to add anything to what Wortman and Earle have already made known respecting the structure of the carpus.

Measurements of Protapirus validus.

Length of skull from base of canine to occipital condyle	242mm
Length of frontals and parietals	151
Distance between postorbital processes of frontals	73
Greatest length of lower jaw	227
Depth of jaw below pm. 2	33
" " " 4	46
Length of inferior diastema	32
" superior "	27
" " premolar molar series	102
" " molar series	53
" inferior premolar-molar series	102
" " molar series	57
" humerus	203
Breadth of distal end of humerus	41
Length of radius	158
Breadth of proximal end of radius	32
Breadth of distal end of radius	29
Length of ulna	216
Height of olecranon process above articular surface	40

Protapirus simplex W. & E.

This species is known only from the superior premolars and fragments of the lower jaw. There is in our collection a lower jaw (11165), with the inferior dentition and both rami nearly complete, found by Mr. H. F. Wells in the *Protoceras beds*, in the same locality as the material just described. Notwithstanding the horizon in which this specimen was found on account of its size and the structure of the premolars I refer it to *Protapirus simplex*. It is smaller than the jaw referred to *P. validus*, and the premolars are in a less advanced stage, the postero-internal cone being quite rudimentary. It differs, also, from *P. validus* in that the cross-crest on pm. 4 is in advance of the same element in pms. 2 and 3, while just the opposite is the case in the latter species. A further structural difference is noticeable in pm. 2; in this tooth in *P. validus* the ridge, which runs forward from the postero-external cone, unites with the antero-external, while in the present specimen it unites with the antero-internal. The principal dental characters of this specimen are shown in figs. 5 and 5*a*, plate III; the last molar is dropped down in each to accommodate the figures to the size of the plate.

Measurements.

Greatest length of jaw	220mm
Depth of jaw below pm. 2	31
" " " m. 3	40
Length of diastema	30
Length of premolar-molar series	98
" molar series	55

Colodon (Marsh).*

The present genus is distinguished from *Protapirus*, which it most resembles, by the presence of a fifth cusp on the last inferior molar; by the reduction of the number of lower incisors to two on either side; by the more molariform superior premolars and by the shape of the postero-external cone of the superior molars, which in the present genus is concave on its external surface. The inferior premolars of *Colodon* are distinct from those of *Protapirus*, in that the postero-external cone is always connected with the antero-external by a low ridge. The second inferior premolar is proportionately very much shorter in *Colodon* than in *Protapirus*.

Although remains of *Colodon* are rarely found, yet five species have already been proposed, viz: *C.* (*Lophiodon*) *occidentalis* (Leidy)†, founded on a last inferior molar; *C. luxatus* (Marsh)‡, founded on a lower jaw in which pm. 2 is absent; *C. dakotensis* (O. and W.)§, founded on a complete superior dentition, with a portion of an inferior dentition and sup. pm. 4, from another individual as a collateral type; *C. procuspidatus* (O. and W.),‖ founded on a superior dentition from one side in which m. 3 is wanting and pm. 1 is injured, and *C.* (*Mesohippus*) *longipes* (O. and W.),¶ founded on a hind foot now provisionally referred to Colodon although first described as *Mesohippus longipes*. Prof. Marsh's type of *C. luxatus* agrees, in size and all essential characters, with Leidy's *occidentalis* in so far as we are able to determine those of the latter, from Leidy's description and figures, and both apparently belong to the same species.

Osborn and Wortman remark, in closing their description of *C. procuspidatus*, that "the only means at present known of distinguishing *C. procuspidatus* from *C. occidentale* (spelling theirs) is by the smaller size and generally less robust character of the latter." They give the horizon as the Metamyno-

* See this Journal, June, 1890, p. 524, and Nov., 1893, p. 411.
† See Extinct Mam. Fauna, Dak. and Neb., p. 239.
‡ Loc. cit.
§ See Bull. Am. Mus. Nat Hist., vol. vii, p. 362.
‖ See Bull Am. Mus. Nat. Hist., vol. vii, p. 364.
¶ See Bull. Am. Mus. Nat. Hist., vol. vii, p. 366, and vol. vi, p. 214.

don layer. Mr. Gidley, who found the specimen, informs me that it is from the *Oreodon beds* below the *Metamynodon layer*. No measurements of the type are given, except to say that, "so far as the measurements are concerned, it agrees very closely in size with *C. dakotensis*." In giving the measurements of the latter species they place in another column, for comparison, corresponding measurements of *C. occidentalis*, but they do not give the measurements of Leidy's type, but those of a smaller individual, referred by Wortman and Earle* to that species; in this way they obtain as the comparative length of the last lower molar of *C. procuspidatus* and *C. occidentalis* ·025 of a meter for the former and ·019 for the latter, while the natural size figure of that tooth in *C. occidentalis*, published by Leidy in his description of the species, measures a little more than ·022 of a meter, showing, that both the smaller measurements and the larger are well within the limits of specific variation. I have therefore considered it best to regard *procuspidatus* as also a synonym of *occidentalis*.

Disregarding *C. longipes*, which may or may not belong to the genus *Colodon*, and which, if it should prove to belong to that genus will quite likely be found to pertain to one of the previously known species, the following is submitted as a key to the species of Colodon.

1. The internal cusps of sup. pms. 2, 3, 4, showing signs of division. Postero-internal cone of inferior pms. smaller than postero-external . . . . . *C. dakotensis.*
2. Two distinct internal cusps on sup. pms. 2, 3, 4. Postero-internal cone of inf. pms. as large or nearly as large as postero-external . . . . . *C. occidentalis.*

Colodon (*Lophiodon*) *occidentalis* Leidy.

Syn. C. luxatus, C. procuspidatus, and *C. longipes?*

There are in our collections several jaws and groups of teeth referable to this species, a crown view of the inf. dentition of one of these (No. 10953) is shown in fig. 6, plate III. It is peculiar in the structure of pm. 2, in which tooth there is but one anterior cusp, a character not seen in any other specimen of *Colodon*. The postero-internal cone on all the premolars in the present specimen equals in size the postero-external. These characters might be regarded as of specific importance, but I prefer to consider them as only individual variations, after studying, with some care, the individual variations in the structure of the teeth of modern Tapirs. In all of the jaws in our collection referred to *C. occidentalis*, the teeth are propor-

* Bull. Am. Mus. Nat. Hist., vol. v, p. 178.

tionately narrower than in those referred to *C. dakotensis*. The present specimen is from the Oreodon beds, below the Metamynodon layer.

Milk dentition: Portions of two lower jaws (Nos. 10507 and 10506, fig. 2 and 7, plate III) in our collection are of interest, inasmuch as they show successive stages in the eruption of the milk and permanent dentitions. In 10507 the first milk molar has been broken off and lost, but the second and third are still in place, and immediately behind them is the first permanent molar fully erupted and behind it m. 2 may be seen just commencing to cut the gum. Beneath the deciduous molars and the anterior half of the first permanent molar, the bone from the inside of the jaw has been removed, exposing the unborn premolars in position. By a glance at fig. 2, plate III, it will at once be seen that these teeth, as well as permanent molar 2, occupy a position in the ramus considerably posterior to that which they will assume when fully erupted. In other words, in the process of eruption they will move forward and upward. No. 10506 has all the deciduous molars in place and the first permanent molar just coming into place. As has been remarked by O. & W., the last two milk molars closely resemble the permanent set, while the first is like the corresponding premolar. These specimens were found by Mr. J. W. Gidley in the upper Titanotherium beds.

Measurements of C. occidentalis (No. 10953 Princ. Coll.)

Length of inf. premolar-molar series	82mm
" " " series	32
" " molar "	50
" last inferior molar	21

Colodon dakotensis, O. & W.

In describing this species, Osborn and Wortman have described the postero-internal cusp of the last lower premolar as double, placing considerable importance upon this character, and the absence of external and internal basal cingula on the superior premolars. The double character of the postero-internal cusp of the last lower premolar is, probably, of little importance, since in their collateral type specimen it is very faint, and has more the nature of a basal cingulum than of a cusp, and moreover, a similar state of affairs is noticeable on some of the smallest of our specimens, referred to *C. occidentalis*. Too much importance should not be given to the presence or absence of basal cingula, which have been shown by Nathusius* to depend, in living animals, largely upon the abundance or

* See Der Schweinschadel.

scarcity of nourishment. The more molariform superior premolars and the usually larger size and more robust character of all the teeth of *C. dakotensis* at once distinguish it from *C. occidentalis.* Several specimens in the Princ. Coll. are referred to this species, one of which (No. 11159) consists of a median ungual phalanx, found associated with a fragmentary lower-jaw, in which the inferior dentition, excepting the canine and m. 3, is complete and in a splendid state of preservation. The ungual phalanx and a crown view of the teeth are shown in figs. 3 and 3a, plate III. This specimen was found by Mr. Wells, and no record was kept as to the horizon; from the nature of the matrix it appears to be from the Oreodon beds below the Metamynodon layer. There may be some doubt as to whether the ungual found associated with the teeth really belongs with them, but from the texture of the bone, color, etc., I believe they pertain to the same individual; it is in shape remarkably like the same bone in Mesohippus, but much larger than that in any species of that genus known from the lower Oreodon beds. It also resembles the same bone in the third digit of *Elasmognathus* and like that bone in this genus and in *Mesohippus* it is notched in front.

The incisors in the present specimen are very large, chisel shaped and their crowns are slightly excavated or cupped. The premolars and molars are very strong.

Measurements of C. dakotensis (No. 11159 Princ. Coll.)

Length of inf. pms. and ms. 1 and 2	75mm
" "	40
Depth of ramus below m. 1	35
Length of ungual phalanx	24
Breadth " "	22

Recent Tapirs.

I do not expect to be able to add much to our present knowledge of recent Tapirs, but rather to collect and condense a part of what is already known of the dental characters, and the osteology of the skull, in the five now generally accepted species; with a list of the synonymy of each, complete, in so far as the literature available will permit. The following key to genera and species is submitted.

A. *Maxillaries greatly expanded superiorly and embracing the mesethmoid cartilage, which in adult specimens is ossified and extends as a bony plate far in front of the nasals. Premaxillaries short and obtuse posteriorly* ..... *Elasmognathus.*

1. Nasals longer than their combined width, and applied to one another throughout the greater part of their length, each usually ossified from a single center..... *E. bairdii.*
2. Nasals broader than long, more or less separated by an anterior prolongation of the frontals, each usually ossified from two separate centers ..... *E. dowi.*

B. *Ossification of mesethmoid cartilage never extending much in front of middle of nasals. Superior border of maxillaries low, and widely separated from each other. Premaxillaries long and acute posteriorly* ..... *Tapirus.*

1. Premaxillo-maxillary suture bisecting alveole for canine. Premaxillary deeply embraced by superior and inferior branches of the maxillary. Sagittal crest broad and low. Nasals broad and long, sup. pm. 2 molariform .. *T. indicus.*
2. Premaxillo-maxillary suture passing in front of alveole for canine. Premaxillary not deeply embraced by superior branch of maxillary. Sagittal crest sharp and high. Nasals broad and short. Sup. pm. 2 molariform..... *T. terrestris.*
3. Premaxillo-maxillary suture passing in front of alveole for canine. Premaxillary scarcely at all embraced by superior branch of maxillary. Sagittal crest sharp and low. Nasals long and narrow. Sup. pm. 2 submolariform .. *T. roulini.*

Tapirus, Brisson (1756) Regne Anim., p. 118.

Syn. Rhinochœrus (Gray), Rhinochœrus (Wagner) in part, Hydrochœrus (Erxleben) in part, Sys. Reg. An., 1777, p. 191.

Tapirus roulini Fischer.*

Syn. T. pinchacus, T. villosus, T. leucogenys, T. œnigmaticus and *Tapir pinchaque.*

A skull and the sup. dentition of the present species are shown in fig. 2, plate V, and figs. 2 and 2a, plate IV, drawn from No. 204 in the Yale osteological collection. *T. roulini* is the smallest and least specialized of all the recent Tapirs. The skull is low, narrow and flat, the nasals are long, pointed, coössified, and posteriorly, they are but little lower than the frontals. The premaxillaries are scarcely at all embraced by a superior arm of the maxillaries and the latter projection is not higher than the embraced portion of the premaxillary. The ossified septum does not extend in front of pos. border of nasal opening. The cavity for lodgment of cartilaginous air sinus is deep, but extends but slightly upon the base of the nasals. The floor of the orbit is shallow but deeper than in *T. indicus.* The foramen magnum is absolutely and relatively larger than in any of the other species. Sup. pm. 1

* Fischer's Synops. Mam. Add., p. 406.

is much longer than broad and the internal cone is situated on the extreme postero-internal angle and is quite rudimentary. The antero-internal cone in sup. pm. 2 is a mere tubercle and the anterior cross-crest is absent.

Tapirus (*Hippopotamus*) *terrestris*, Linn.*

Syn. T. americanus, T. anta, T. suillus, T. laurillardi, T. equadorensis.

The principal characters of the skull and sup. dentition of this species are shown in fig. 1, plate V, and 1 and 1a, plate IV, which have been drawn from No. 157 in the Yale Coll. The present species seems to be most closely related to the preceding; the skull, like that of the former, is compressed and there is a sharp sagittal crest in both; but in the present species the sagittal crest is convex antero-posteriorly and elevated far above the nasals, which are short and broad in marked contrast to those conditions which have been found in *T. roulini*. The premaxillaries have an extended contact with the maxillaries and are slightly embraced posteriorly by a superior branch of the latter which is not elevated above the premaxillary. The excavation for the air sinus is mainly in the frontals and maxillaries, near the base of nasals and does not encroach much upon the latter. The first sup. premolar is nearly as broad as long and the internal cone is near the middle of the tooth. Sup. pm. 2 is entirely molariform.

Tapirus indicus Desm.†

Syn. T. sumatranus, T. maylayanus, T. bicolor, T. me.

A skull and sup. dentitian of *T. indicus* are shown in figs. 3, plate V, and 3 and 3a, plate IV, drawn from No. 200 in the Yale Coll. As has been noticed by Gill the present species more nearly resembles species of *Elasmognathus* than do either of the other species of *Tapirus*, among the points of resemblance the following are noteworthy. The premaxillaries are embraced by the maxillaries and the superior branches of the latter are produced above the premaxillaries and approach each other medially. The mesethmoid cartilage is ossified as far forward as the middle of the nasals in adult specimens. The frontals are broad and abruptly elevated above the base of the nasals, precisely as in Elasmognathus. The premaxillo-maxillary suture bisects the alveole for the canine, in this respect *T. indicus* is unique among modern Tapirs, and I have found this character absolutely constant in

* Sys. Nat., 10th ed., 1758. † Desm. Mam., p. 411.

all the skulls I have been able to examine and in the published figures of them. The nasals are long, broad posteriorly, narrow anteriorly and separated throughout their entire length, near their base there is a deep excavation for the lodgment of the cartilaginous air sinus. Sup. pm. 1 is longer than broad, the internal cone is placed farther forward than in *T. roulini*. The cross-crests in sup. pm. 2 are not complete in the present specimen, but I notice that in other specimens they are quite complete.

Elasmognathus Gill.*

This genus has not been generally accepted, but the characters assigned to it by Dr. Gill are constant and seem to be of generic importance. In addition to the characters already pointed out. I may mention the extreme breadth of the top of the skull which may almost be described as without a sagittal crest, and the invariably complete molariform condition of sup. pm. 2. Species of the present genus rival in size *T. indicus*, the largest of the species of *Tapirus*, and include the most specialized forms belonging to the Tapiridae.

Elasmognathus bairdii Gill.†

The principal characters of the skull and sup. dentition of this species are shown in figs. 4, plate V, and 4 and 4a, plate IV, drawn from No. 515 in the Yale Coll. The ascending posterior arm of the maxillaries, which articulate with the lachrymals and frontals is much compressed and entirely concealed by the latter bones, when the skull is viewed from the side. The premaxillary is short and obtusely pointed, posteriorly. The post-tympanic and postglenoid processes approach each other inferiorly but do not meet. The nasals are longer than broad, are closely applied throughout their entire length and coössified in old individuals; they usually ossify, each, from a single center, and posteriorly, they are but little separated by the anterior median prolongation of the frontals.

Elasmognathus dowi Gill.‡

In general, the skull and dentition of the present species resembles so closely those of the preceding that it is not necessary to figure the latter. Alston§ has shown that most of the specific characters ascribed to *E. dowi* are quite variable, and hardly of specific importance. He says on page 98 of the work

* See Proc. Phil. Acad Sci., 1865, p. 183.
† See Proc. Phil. Acad. Sci., 1865, p. 183.
‡ See this Journal, 1870, p. 142.
§ See Biologia Centrali-Americana, Mammalia by Edward R. Alston, 1879–1882.

just cited: "The comparison of a sufficient series of skulls in any species of Tapir shows the existence of a very remarkable extent of individual variation in minor dental and cranial characters; and I have not found any of the differences pointed out by Dr. Gill as distinguishing *T. dowi* from *T. bairdii* to be constant, except the extraordinary modification of the fronto-nasal region." After figuring and describing at some length the different characters in the region of the nasals, on page 100, Alston summarizes these characters as follows:

"1. *T. bairdii.* Nasals well developed, each ossified from a single center, separate throughout life, thick at their base, and articulated with one another for the greater part of their length."

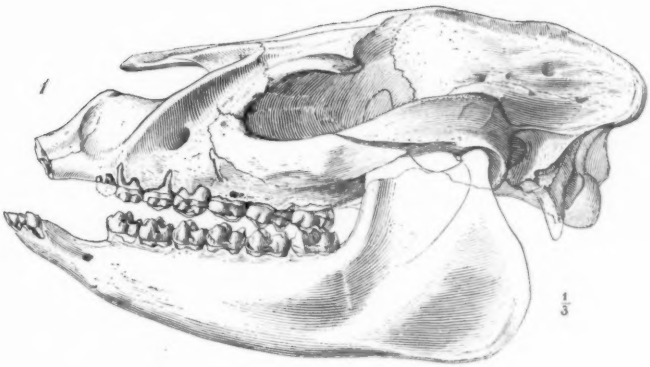
"2. *T. dowi.* Nasals very small, each ossified from two centers, thin, more or less separated from one another by an anterior prolongation of the frontals, with which they become partially or entirely ankylosed before the animal reaches maturity."

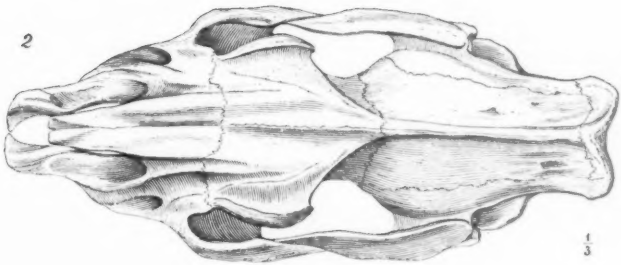
Had Alston had more material he would doubtless have arrived at the same conclusion regarding the nasal characters that he did in regard to those of other parts of the skull. I find these characters exceedingly variable, and in the very extensive collection of skulls of *Elasmognathus* in the National Museum, which I have had the privilege of examining and figuring, every gradation between these two types of nasals is shown. I have selected a series of five of these skulls, showing as many different degrees of variation, and have had the fronto-nasal region in each drawn, and they are shown here in pl. III, figs. A, B, C, D, E. From an examination of these figures in connection with what has already been said, it will at once be seen that as yet no character has been found by which it is possible always to distinguish *E. dowi* from *E. bairdii*, and they might be considered synonyms, although I have preferred to retain both, and consider the former as the less specialized of the two, and the direct ancestor of the latter, which has not as yet been fully differentiated from it. It might better be considered as a sub-species.

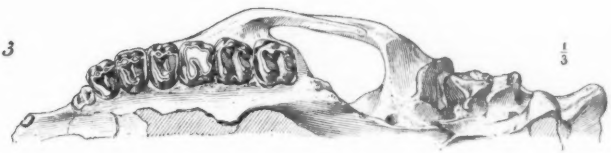
Phylogeny.

Wortman* and Earle in their most excellent paper entitled "*Ancestors of the Tapir from the Lower Miocene of Dakota*," have reviewed very fully the work done by Marsh, Cope, Scott and Osborn on the phylogeny of the Tapirs. They (Wortman and Earle) derive the true tapirs from the Wind River genus

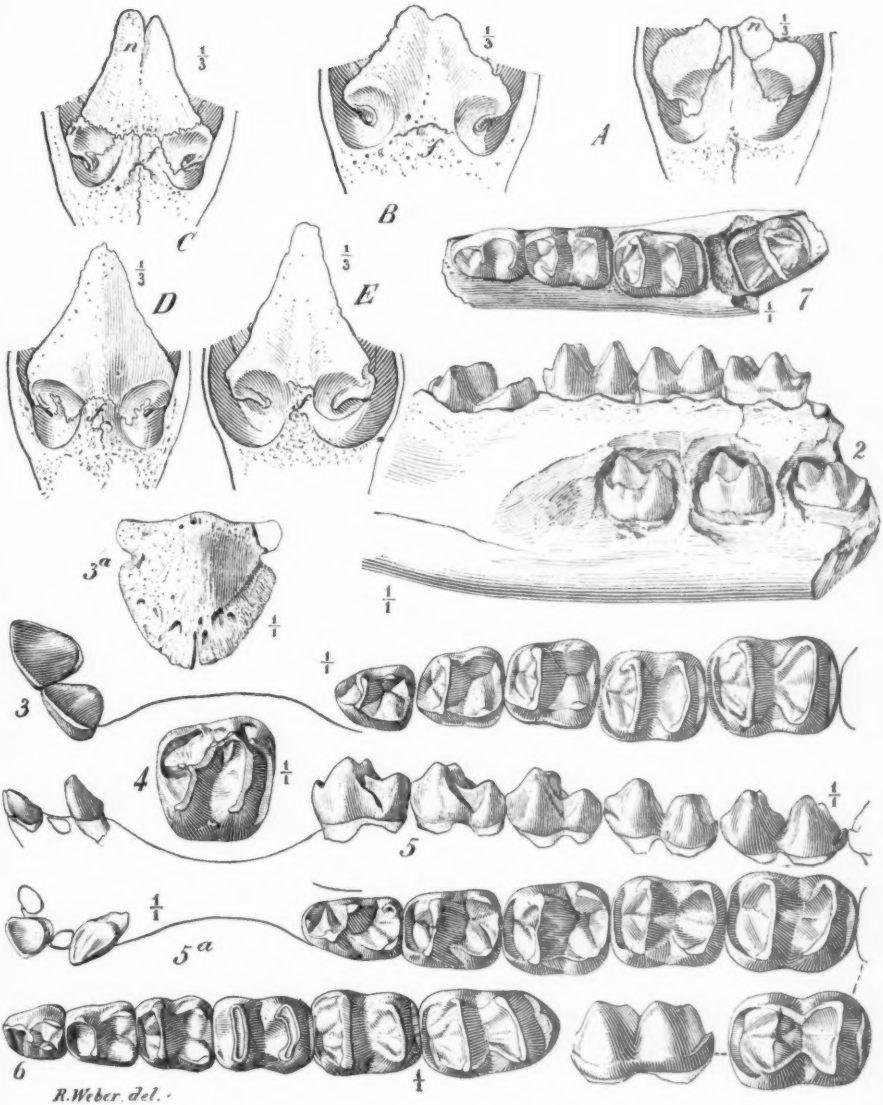
* See Bull. Am. Mus. Nat. Hist., vol. v, pp. 159–180.







R. Weber, del.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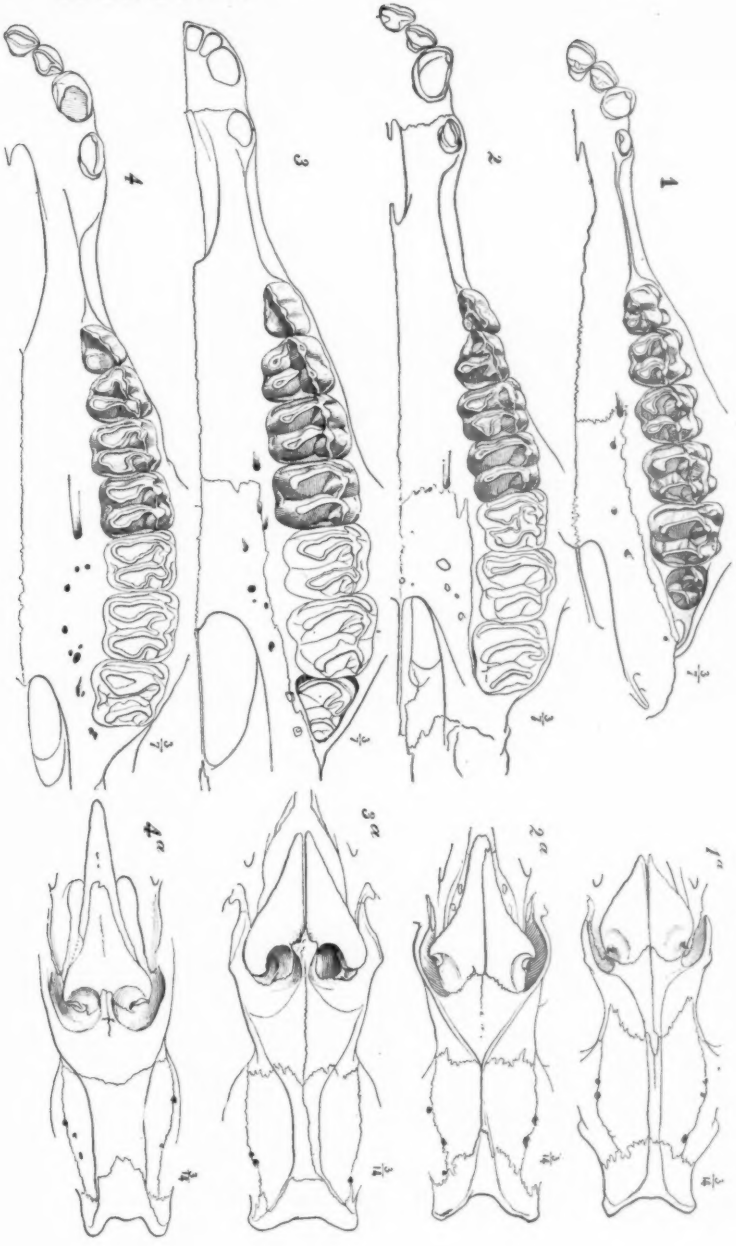
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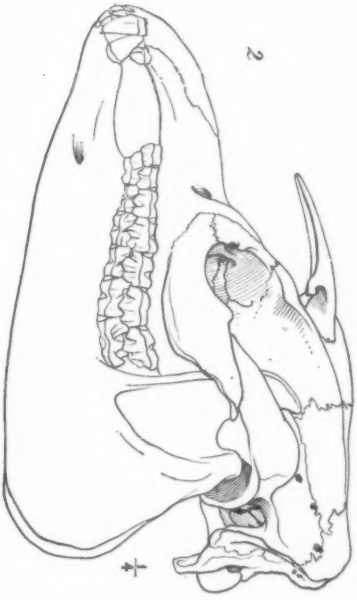
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Systemodon through the intermediate forms *Isectolophus* (*Helaletes*) *latidens* of the Bridger, *Isectolophus annectens* from the Uinta, *Protapirus simplex* and *P. obliquidens* from the White River and perhaps *Tapiravus* from the Loup Fork. They cite as evidences against this line of descent, the union of the protoloph with the parastyle instead of the paracone in both species of *Isectolophus* and the submolariform character of sup. pms. 3 and 4 in that genus as described by Osborn.* I have carefully examined both of these types and can say that the union of the protoloph is with the paracone rather than the parastyle, the real union being with the ectoloph a little in front of the paracone. In regard to the sup. pms. Prof. Osborn says (on page 519 of the paper just cited): "These are wanting in the Uinta specimens, but the Bridger species which was formerly referred by us to *Helaletes* (*H. latidens*) is closely related to *Isectolophus*, if not generically the same, and shows double internal lobes upon both pm. 3 and pm. 4;" and just below on the same page in his *Generic characters* he says, "Fourth and probably third premolars in both jaws submolariform or with double internal cones." These are certainly errors of observation and description, since in sup. pm. 4, which is the only superior premolar complete and in position in the type of *H. latidens*, *the internal cone is absolutely simple and without the faintest signs of division*, the same may be said of the only sup. pm. at present known of *Isectolophus annectens*. Prof. Osborn further states on page 521 that the first inferior premolar abuts against the canine; and on page 519, that there is no diastema behind the canine, these are characters not shown in any of the type specimens of the genus; and if we stop to consider the characters which obtain in this region of the skull in the White River Tapiroids, together with the extreme conservativeness of this entire group in accomplishing any dental or other changes, we may infer that it is quite probable, that in the Uinta Tapiroids, there was a considerable post-canine diastema, with a marked constriction of the symphysis of the lower jaw, otherwise we shall have to conclude that the Tapirs, toward the close of the Uinta, began to progress very rapidly, and in the interim between that and the beginning of White River times they outstripped all other Perissodactyls in accomplishing anatomical changes, a very improbable assumption.

After studying carefully all the material referable to *Isectolophus annectens* I can only substantiate the views of Scott, Osborn, Wortman and Earle in referring *Isectolophus* to the *Tapiridæ*. I do not consider *Isectolophus* (*Helaletes*) *latidens* from the Bridger as belonging to the genus *Isectolophus*.

* The Mam. of the Uinta Form. Trans. Am. Phil. Soc., 1889, pp. 461–572.

There are marked differences in the structure of the sup. true molars in the two species and when the complete dentition of the Uinta species is known, the dental formula and arrangement of the teeth will doubtless be found to differ in the two. If *Isectolophus* (*Helaletes*) *latidens* can be shown to differ generically from *Helaletes* it should be made the type of a new genus. I have never seen any of Prof. Marsh's types of *Helaletes* and his descriptions do not permit of an identification of other material.

The discovery of a nearly complete skull of *Protapirus* with characteristic tapirine characters, already pointed out, may be considered as additional evidence in favor of Wortman and Earle's views in considering that genus as the White River ancestor of the *Tapirs*. In taking this view of the question, however, the fact must not be lost sight of, that in *Protapirus* the character of the metacone of the sup. molars is not what we should expect to find in a White River *Tapir*, and the inferior, external, lateral incisor is much smaller than we should expect it to be, since it persists in recent Tapirs and is even proportionately larger than in *Protapirus*. The metacone in *Protapirus* is placed father in, and is less prominent and not so convex externally as in *Isectolophus*, while the same element in recent Tapirs is more prominent and has a more external position than in *Isectolophus*. Thus, according to our present phylogenetic arrangement we should have to allow for first a gradual shifting inward of the position of this cone followed by a period when it commenced to move outward to its normal position in modern *Tapirs;* a rather extreme case of oscillation but not entirely inconsistent with what Scott has shown to have taken place in the Equine series.

Very little is known of the American Miocene representatives of the Tapir line. Prof. Marsh has mentioned the occurrence of two Miocene species of Tapiroids which he considers as standing ancestral to the Tapirs. One of these is from the Miocene of New Jersey and the other is from the Loup Fork or late Miocene (early Pliocene of Marsh) from east of the Rocky Mountains, no more definite locality being given by Marsh. These specimens are made the type of a new genus *Tapiravus;* the one from New Jersey is described as *Tapiravus validus*, while the one from the west is called *T. rarus*. I have never seen either of these specimens and they have not been figured, and are only very briefly described by Prof. Marsh. There would seem to be little doubt that they belong to the direct line leading to the recent Tapirs.

In Europe the paucity of Tapir remains in the Miocene is almost as marked as in America. In *Tapirus helveticus* of Meyer, from the lower Miocene of Eselsberg near Ulm, we

doubtless have one of the direct ancestors of the modern Tapir. In this species sup. pm. 4 is entirely molariform except that the posterior cross-crest is not complete. Sup. pm. 3 is in the same stage as sup. pm. 2 in *T. roulini* of recent Tapirs. *Tapirus helveticus* Meyer is perhaps the European equivalent of *Tapiravus validus* Marsh, from New Jersey. The European species should be referred to the latter genus rather than to Tapirus. In regard to the American species at present referred to Protapirus, there may be considerable doubt as to whether they should not be referred to a distinct genus; from Filhol's description and figures there would seem to be a considerable difference in the relations of the protoloph to the parastyle in the sup. true molars and in the structure of the posterior cross-crest in sup. pm. 4. The importance of these differences can only be determined by an actual comparison of the specimens.

Of recent Tapirs it can be pretty well demonstrated that *Elasmognathus bairdii*, the most specialized of all, has been derived from *T. roulini* directly through *T. terrestris* and *E. dowi;* while *T. indicus* had a common ancestry and became separated from the others, probably in late Miocene times, since when it has paralleled *Elasmognathus* in some of its characters though not showing the same degree of specialization.

In regard to *Colodon* and the earlier genera of *pseudo-tapirs*, I cannot agree with Osborn and Wortman that their line of descent has been entirely distinct from that of the true *Tapirs*. On account of the, in many respects, very similar tooth and foot structure of the two, it would seem that they were both derived from a common Bridger ancestor, most likely some one of the species now referred to *Helaletes* and which had its immediate ancestor in *Systemodon*. The true genus *Helaletes* with sup. pms. 3 and 4, already molariform according to W. and E., terminates a third line, and is descended directly from Heptodon of the Wind River.

The figures in the plates accompanying this paper were drawn by Mr. Rudolph Weber. I wish here to express my thanks to Prof. Scott for his kindness in allowing me to describe the important and rare skull of *Protapirus* as well as the other fossil material. To Prof. Marsh I am especially indebted for the free use of the very complete collection of skulls and skeletons of recent Tapirs in the Yale Museum. I wish also to thank Mr. F. A. Lucas of the National Museum and Prof. Osborn and Dr. Wortman of the Am. Mus. of Nat. Hist. for the use of material in their charge.

Princeton, N. J., Jan. 13, 1896.

EXPLANATION OF PLATES.

Plate II.

Figure 1.—Side view of skull of *Protapirus validus*, $\frac{1}{3}$ natural size.
Figure 2.—Top " " " " " "
Figure 3.—Bottom " " " " " "
Figure 4.—Crown view of inf. dentition of same, $\frac{3}{4}$ natural size.

Plate III.

Figures A, B, C, D, E.—Comparative series of nasals of *E. dowi* and *E. bairdii*
Figure 2.—Inside view of young lower jaw of *Colodon occidentalis*, showing milk and permanent teeth.
Figure 3.—Crown view of inf. dentition of *Colodon dakotensis*.
Figure 3*a*.—Ungual phalanx of *Colodon dakotensis*.
Figure 4.—Crown view of sup. m. 3 of *Colodon* sp.
Figure 5&5*a*.—Side and crown view of inf. dentition of *Protapirus simplex*. M. 3 dropped down in each to accommodate size of plate.
Figure 6.—Crown view of inf. dentition of *Colodon occidentalis*.
Figure 7.—Crown " " milk dentition of " "

Plate IV.

Figure 1.—Crown view of sup. dentition of *Tapirus terrestris*, $\frac{3}{7}$ nat. size.
Figure 2.— " " " " *roulini*, " "
Figure 3.— " " " " *indicus*, " "
Figure 4.— " " of *Elasmognathus bairdii*, " "
Figure 1*a*.—Top view of nasals and crest of *Tapirus terrestris*, $\frac{3}{14}$ nat. size.
Figure 2*a*.— " " " " *roulini*, " "
Figure 3*a*.— " " " " *indicus*, " "
Figure 4*a*.— " " " " *Elasmognathus bairdii*, $\frac{3}{14}$ nat. size.

Plate V.

[All figs. $\frac{1}{4}$ nat. size.]

Figure 1.—Side view of *Tapirus terrestris*.
Figure 2.— " " *roulini*.
Figure 3.— " " *indicus*.
Figure 4.— " *Elasmognathus bairdii*.

ART. XVIII.—*A method for the Separation of Selenium from Tellurium based upon the difference in volatility of the Bromides;* by F. A. GOOCH and A. W. PEIRCE.

[Contributions from the Kent Chemical Laboratory of Yale College—XLIX.]

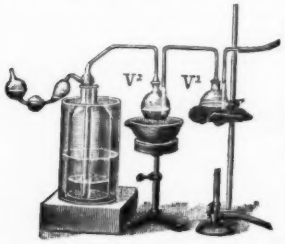
IT has been shown in previous articles from this laboratory* upon the reducibility of selenic acid by the action of the halogen acids, that when small amounts of selenic acid are boiled in aqueous solution with potassium iodide and hydrochloric acid, selenium is precipitated, while the iodine set free simultaneously may be collected in the distillate, estimated, and taken as the measure of the selenic acid originally present; that if the iodide is omitted from the mixture, so that the hydrochloric acid alone shall be the reducer, the reduction proceeds only to the point of formation of selenious acid, provided the boiling is not continued after the hydrochloric acid has reached the condition of half-strength at which it boils unchanged under normal atmospheric pressure; and that a solution of selenic acid, potassium bromide, and sulphuric acid of regulated dilution and proportions also yields under defined conditions selenious acid as the product of reduction. When, however, the ebullition of a solution of selenious acid in hydrochloric acid is continued after the acid has reached the condition of half-strength, traces of selenium appear in the receiver and connecting tubes, the distillate sets free iodine from potassium iodide, and it is evident that the selenious acid is undergoing further reduction. So also when the boiling of the mixture of sulphuric acid, potassium bromide, and selenious acid is pressed beyond the point at which the solution begins to be colored, selenium appears in traces in the tube leading to the receiver and the distillate liberates iodine from an iodide. Obviously the conditions have been at this time reached in the processes of concentration when selenium tetrachloride and selenium tetrabromide, respectively, are forming from the acid, and that the appearance of the elementary selenium is due to partial decomposition of the halogen salts. We have observed more recently phenomena of a similar nature (as would naturally be expected under the conditions), when aqueous solutions of selenious acid, phosphoric acid, and sodium chloride are submitted to distillation; that is to say, there comes a time in the process of boiling such mixtures when the appearance of elementary selenium and the action of the distillate upon potassium iodide make evident the volatilization and partial decomposition of the selenium compounds of the

* This Journal, I, 254, 400, 402.

halogens, and the further continuance of the treatment results in the more or less complete removal of the selenium compounds to the distillate. From the mixture containing the phosphoric acid, selenious acid, and sodium chloride we have been able to secure only a partial volatilization of the selenium chloride. The transfer of the selenium bromide, however, from the mixture of the acids and potassium bromide is rapid and complete, and this fact points out a possible method for the separation of selenium from substances which do not form volatile products under similar conditions of treatment. Tellurium proves to be such a substance, and the work to be detailed has to do with a process for the separation of selenium from tellurium, based upon the volatility of selenium tetrabromide and the non-volatility of tellurium tetrabromide under definite conditions.

The selenious acid which we used was made by dissolving in water a known weight of the white, crystalline, anhydrous dioxide prepared from pure selenium by oxidation with nitric acid, treatment in solution with barium hydroxide to remove selenic acid, and repeated sublimation in a current of oxygen. The tellurium was obtained in solution in its lower condition of oxidation by dissolving in potassium hydroxide a known weight of tellurium dioxide (made by oxidizing presumably pure tellurium by nitric acid and igniting the product at a low red heat), neutralizing with phosphoric acid, and redissolving in a sufficient excess of that acid the precipitate formed in the process of neutralization.

In our preliminary experiments we made use of a form of apparatus previously employed for similar purposes and described in former articles from the laboratory, viz: a Voit flask, serving as the retort, sealed to the inlet tube of a Drexel wash-bottle, used as a receiver, the outlet tube of which was trapped by sealing on Will and Varrentrapp absorbtion bulbs. Later the apparatus was changed to the form shown in the accompanying figure by introducing a second Voit flask, in order that the selenium might be estimated in the distillate more conveniently.



Into the first Voit flask, V^1, were put measured amounts of the solution of selenious acid with 20 cm^3 of syrupy phosphoric acid (sp. gr. 1·70), 1 grm. of potassium bromide, and water enough to make the entire volume of liquid 50 cm^3. The second flask, V^2, contained about 15 cm^3 of water, and was kept cool by immersion in water.

The Drexel bottle and bulbs contained a solution of potassium iodide. A current of carbon dioxide was passed slowly through the apparatus to secure quiet ebullition and to aid in the transfer of the distillate to the receiver. Upon applying heat to the first flask, V^1, the solution boiled quietly and without change until the volume of liquid had decreased to about 30 cm^3, when traces of red selenium began to deposit in the tube joining the first and second flasks. When the volume had further diminished to about 25 cm^3 the liquid began to take on color, darkened rapidly, and evolved bromine, which at once attacked the selenium previously deposited. The greater part of the bromine was absorbed in the second flask, V^2, but a trace found its way to the Drexel bottle, in which it set free a slight amount of iodine from the iodide, as was afterward proved by the effect upon starch. As the operation progressed, an orange-yellow crystalline solid, presumably selenium tetrabromide for the most part, appeared in the tube where the selenium had been, while a dark oily liquid, consisting largely, no doubt, of the monobromide, condensed in drops upon the walls of the flask and returned to form a floating layer upon the hot liquid. Finally, when the volume had diminished to 15 cm^3, the liquid had become perfectly clear and colorless, white fumes of hydrobromic acid were evolved, and the tube between the two flasks had been cleared. At this point the operation was stopped and the apparatus allowed to cool. The addition of potassium iodide to the contents of the first flask neither liberated iodine nor precipitated selenium, and so proved that no reducible compound of selenium still remained in that flask. The amount of selenium which had been volatilized we determined directly by means of a method worked out in this laboratory and to which reference has already been made.* We introduced into the second flask, V^2, which now contained (beside a trace of selenium corresponding to the slight amount of bromine which had escaped to the Drexel bottle) the colorless selenious acid regenerated by the action of the water and free bromine upon the mixed bromides which had distilled, 1 grm. of potassium iodide and 5 cm^3 of hydrochloric acid and, after removing the first flask, V^1, and connecting the carbon dioxide generator with the inlet tube of V^2, boiled the solution ten minutes while a current of carbon dioxide passed through this apparatus. At the end of this time the iodine set free by the action of the iodide had been almost completely removed to the Drexel bottle, leaving a nearly colorless solution containing particles of dense, crystalline selenium. The iodine in the receiver, including of course the small amount set free by the bromine which reached the

* Gooch and Reynolds, this Journal, I, 254.

receiver in the first stage of the process, together with the small amount remaining in the flask, was titrated with sodium thiosulphate and taken as the measure of the selenium dioxide acted upon originally. In this way we obtained the following results:

SeO_2 taken. grm.	SeO_2 corresponding to iodine found in the distillate. grm.	Error. grm.
0·0366	0 0372	0·0006 +
0 0366	0·0377	0·0011 +
0·1098	0·1090	0·0008 —
0·1098	0·1101	0·0003 +

It is obvious from these results that the iodine finally found in the receiver is actually an accurate measure within reasonable limits of the selenium dioxide originally put into V^1 and volatilized therefrom by the action of phosphoric acid and potassium bromide.

When tellurium dioxide is subjected to similar treatment the phenomena are different. The solution containing the tellurous acid, potassium bromide, and phosphoric acid, in the proportions used in the experiments with selenious acid, colors at about the same degree of concentration at which the solution containing the selenious acid began to darken. As the concentration progresses the color deepens, ruby red crystals (probably hydrated tellurium tetrabromide) form, which accumulate upon the walls of the flask and turn yellow, and when the volume of the solution is diminished to 15 cm^3 a green vapor begins to distil. During the process no iodine is set free in the Drexel bottle, and upon stopping the boiling we found that the addition of potassium iodide to V^2 liberated no iodine, even when the boiling had gone so far that a trace of the green vapor had condensed and run into the water in the flask. In view of these facts it seemed probable that the process of treatment which we have described might be applied to the determination of selenium associated with tellurium. In the following experiments, made to test the point, tellurium dioxide was weighed out and dissolved in strong potassium hydroxide, the alkali was neutralized and the precipitate thus formed was redissolved by phosphoric acid, and 20 cm^3 of the acid of sp. gr. 1·70 were added in excess. To the solution were added definite amounts of selenium dioxide taken in a standardized solution and 1 grm. of potassium bromide, and the whole was introduced into the first flask, V^1, with enough water to make the entire volume of the solution 50 cm^3. The second flask, V^2, contained 10 cm^3 of water, and the Drexel bottle and trap were charged with a solution of potassium iodide. Carbon

dioxide was passed through, and the solution in V^1 was boiled. The phenomena of each individual set of experiments with the selenious and tellurous acids occurred now together—the coloring of the liquid, the evolution of bromine, the distillation of the selenium bromides, the crystallization of the tellurium tetrabromide, the disappearance of the selenium compounds from the connecting tube, and the final stopping of the distillation when the volume of the residue has diminished to 15 cm^3. After cooling, the first flask V^1 was removed, 1 grm. of potassium iodide and 5 cm^3 of hydrochloric acid were added to the contents of the second flask, V^2, the current of carbon dioxide was again started through the apparatus, the mixture was boiled ten minutes, and the iodine in the flask, receiver and trap was determined by titration with sodium thiosulphate and taken as the measure of the selenium dioxide. In some preliminary experiments trouble was experienced in removing the last traces of the selenium bromides held back mechanically by the oily tellurium compound which collected upon the walls of the distillation flask and in the connecting tube; but the difficulty was satisfactorily overcome by cloaking the flask with a mantle of asbestos board and flaming the connecting tube gently toward the close of the process of distillation. The results obtained are gathered in the following table:

TeO_2 taken. grm.	KBr taken. grm.	H_3PO_4 (Sp. gr. 1·70) taken. cm^3.	Final volume. cm^3.	SeO_2 taken. grm.	SeO_2 found. grm.	Error. grm.
0·1	1	20	15	0·0733	0·0735	0·0002 +
"	"	"	"	0·0997	0·0995	0·0002 —
"	"	"	"	0·1004	0·1003	0·0001 —
"	"	"	"	0·0916	0·0914	0·0002 —
"	"	"	"	0·0997	0·0995	0·0002 —
"	"	"	"	0·1010	0·1014	0·0004 +
"	"	"	"	0·1015	0·1008	0·0007 —
"	"	"	"	0·1019	0·1022	0·0003 +
"	"	"	"	0·1010	0·1012	0·0002 +
"	"	"	"	0·1002	0·1000	0·0002 —
"	"	"	"	0·1006	0·1004	0·0002 —
"	"	"	"	0·1006	0·1001	0·0005 —

Obviously the error of the process, when carefully conducted and applied to the amounts of material which we have employed, is very small.

Art. XIX.—*Results of Recent Pendulum Observations;** by G. R. Putnam.

Some additional relative measurements of the force of gravity were made by the Coast and Geodetic Survey during the summer of 1895. This work was done at certain primary telegraphic longitude stations of the Survey, and as it was incidental to the longitude work, the points were not selected with especial reference to their value as gravity stations. Notwithstanding this fact and their small number, they happen to be so located as to be of interest in several ways, and it is therefore thought desirable to give this preliminary summary of the results. The observations were made with the Mendenhall half-second pendulums, and the instruments and methods used were almost identical with those employed by the writer at 26 stations in 1894 and already fully described.† About the only change was in the use of two knife-edges instead of one. For the purpose of further insuring the independence of the pendulums, two pendulums were always swung upon one knife-edge and the third upon the second knife-edge. The pendulums were swung at the base station in Washington in January, 1895, and again after the return from the south in August; the mean corrected period of the three was in January ^{s}·5007121, and in August ^{s}·5007113. This difference may in part be due to some slight uncertainty in the temperature coefficient. To compare these periods with those obtained by the same pendulums at Washington in 1894, a small correction of +^{s}·0000004 must be added to these means to allow for the fact that one pendulum was swung on a different knife-edge, which diminished the period of that pendulum. When this comparison is made there is found a slight but unimportant diminution in the average period, as seems to be the general tendency of the effect of use on pendulums. Because of the fact that Austin, Texas, formed one end of several of the longitude lines, opportunity was there afforded to make some additional tests in regard to the agreement of repeated but entirely independent determinations. A full series of observations was made at the end of April in a very favorably located basement room in the granite Capitol of the state of Texas. The apparatus was then used at Laredo and Galveston

* Published by permission of the Superintendent of the U. S. Coast and Geodetic Survey. Read before the Philosophical Society of Washington, Jan. 18, 1896.

† Report U. S. Coast and Geodetic Survey for 1894, Appendix No. 1; also "Results of a trans-continental series of gravity measurements;" Bulletin Philosophical Society of Washington, vol. xiii, p. 31.

and brought back to Austin, where early in June it was set up in the basement of the State University, somewhat more elevated and to the northward of the Capitol. Here two complete and independent sets of observations were carried out, with the pendulums swinging in the prime vertical in the first set and in the meridian in the second set. After applying a correction to the Capitol observations to reduce to the elevation and latitude of the University, the corrected periods were found to be:—

	Pendulum A4.	Pendulum A5.	Pendulum A6.	Mean.
	s.	s.	s.	s.
Capitol	·5010508	·5008777	·5008407	·5009231
University, prime vertical,	10508	8784	8417	9236
University, meridian	10504	8784	8424	9237

A comparison of the last two results indicates, as was anticipated, that the position of the planes of oscillation with respect to the meridian has no effect on the period.

Favorable locations, always in basements of buildings, were found for the observations at the other stations also, with the exception of New Orleans. At Laredo the instruments were in the commissary of Fort McIntosh, at Galveston and Calais in high-school buildings, and at New Orleans in the City hall. The necessity of being near the longitude station compelled this location in the latter place, though on account of close proximity to a heavily travelled street and the unstable nature of the underlying ground it was unfavorable, as the jar of passing vehicles was quite noticeable. The coincidences were sometimes irregular, but the periods of the three pendulums are in good accord and no discrepancy appears between the day and night observations.

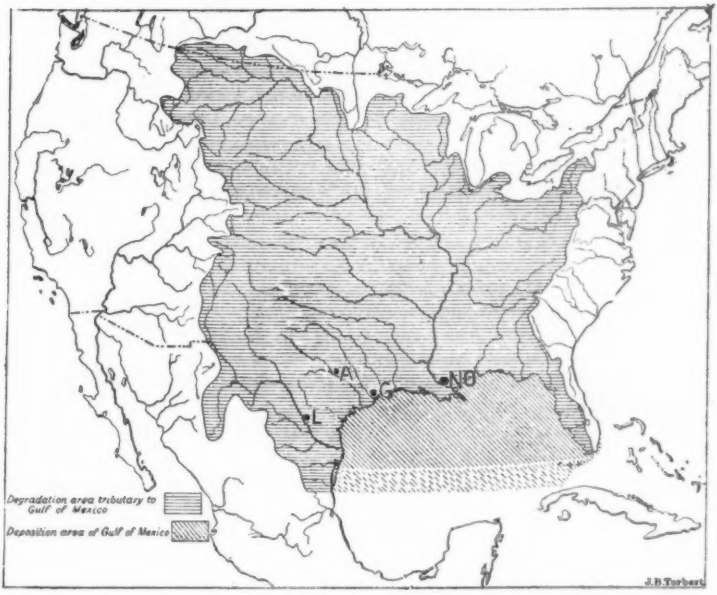
The following table gives a summary of the results for these stations, the relative values of gravity being based as before on that provisionally adopted for Washington, and the computed values being derived from a theoretical formula depending on Clarke's figure of the earth (1880). The observed values have been reduced to sea level by two methods, first Bouguer's, in which the attraction of the entire mass above sea level is subtracted, and second, Faye's, in which in the attraction term only the difference from the average surrounding elevation is allowed for (in this case the average within a radius of 100 miles has been estimated as before). The usual elevation and topographical corrections are of course included in both of these methods. The residuals observed minus computed gravity are given in the table for these two methods of reduction to sea level.

Station.	Latitude north.	Longitude w. of Greenw.	Elevation.	g observed.	g reduced to sea level.		g computed.	Residuals, g reduced minus g computed.	
					Bouguer's reduction.	Faye's reduction.		Bouguer's reduction.	Faye's reduction
	° ′ ″	° ′ ″	meters	dynes	dynes	dynes	dynes	dynes	dynes
Austin, Texas (Capitol)	30 16 30	97 44 16	170	979·274	979·307	979·333	979·369	—·062	—·036
Austin, Texas (University)	30 17 11	97 44 14	189	979·269	979·306	979·332	979·370	—·064	—·038
Laredo, Texas	27 30 29	99 31 12	129	979·068	979·095	979·109	979·160	—·065	—·051
Galveston, Texas	29 18 12	94 47 29	3	979·258	979·259	979·259	979·294	—·035	—·035
New Orleans, La.	29 56 58	90 04 14	2	979·310	979·311	979·311	979 344	—·033	—·033
Calais, Maine	45 11 11	67 16 54	38	980·618	980·626	980·632	980·647	—·021	—·015

The continuation of the investigation of the question of reduction to sea level and of the anomalies of gravity is essential to a satisfactory application of pendulum observations in geodesy. The four stations in the south are of interest in this connection as well as from a geological point of view because of their comparative location. Two, Austin and Laredo, are situated toward the interior about 150 and 135 miles (241 and 217 kilometers) respectively from the Gulf coast, and in a region of erosion. Galveston is on a sandy island close to the main land, from which it is separated by a bay into which empty some small rivers. New Orleans is on the banks of the Mississippi in the midst of the vast alluvial region built up by that river, but is about 85 miles (137 km.) from the present mouth of the river. Galveston and New Orleans are about equally distant (nearly 100 miles or 161 km.) from the 100 fathom (183 meter) curve in the Gulf of Mexico, beyond which line the water depths rapidly increase. It has been estimated that an area of about 1,800,000 square miles is drained by the Mississippi, Rio Grande and neighboring rivers emptying into the Gulf of Mexico from the north, and that the enormous amount of sediment carried by these rivers is deposited within an area of 300,000 square miles along the northern part of the Gulf.* If this added load accumulating for ages and displacing sea water of only about one-third its density, were sustained by a rigid earth, it would seem that there must be an effect on the force of gravity measured at the surface which would be quite within the range of observation, and gravity in the loaded region would be found greater than normal. If, on the other hand, there existed a perfect condition of equilibrium, and an area so loaded continually adjusted itself and sank in proportion to the load, in accordance with the theory of isostasy, we would expect to find the force of gravity quite normal. Should there be a lag between cause

* These drainage and deposition areas are shown in the map, here reproduced, with the author's permission, from Mr. McGee's paper, later referred to. The positions of the gravity stations are also shown.

and effect, that is, should the load accumulate to a certain extent before the sinking occurred because of the partial rigidity of the crust or some other retarding cause, we would again expect to find gravity in excess, but only to a small amount. It is of interest, therefore, in this connection to examine the gravity residuals at the four southern stations (differing as they do but little in latitude) as given in the last two columns of the table. The minus sign indicates a defect of gravity as compared with that given by the theoretical



Stations: N. O., New Orleans; G., Galveston; A., Austin; L, Laredo.

formula used, but it is only the comparative values between the coast and interior stations that need be considered here. There is practically no difference in the results for the two coast stations, New Orleans and Galveston. With Bouguer's reduction, gravity at the coast stations, however, is apparently about ·030 dyne greater than at the interior stations, but this is probably due to the fact that the interior stations are more elevated, as negative residuals almost invariably appear in elevated regions with this method of reduction. With Faye's reduction, gravity at the coast stations is ·017 dyne greater than

at Laredo and only ·003 greater than at Austin, or an average excess of ·010.* As far as it is safe to draw an inference from so small a number of observations (and considering the unfavorable location of the station at New Orleans), gravity is apparently slightly in excess near the Gulf coast as compared with interior stations. A determination nearer the present delta† of the Mississippi would be of interest in this connection, as well as observations in the same latitude on the other coasts of the continent. The smallness of the differences found indicate a close approach to the condition of hydrostatic equilibrium in this region. The fact that the slight excess is at the coast stations points possibly to some retardation in reaching this condition. It is interesting to compare the conclusion reached by Mr. McGee in discussing the condition of the same region as deduced from geological and other considerations, in these words: "So the data relating to the condition of the earth's crust derived from the modern Gulf of Mexico indicate that throughout the vast geologic province of southeastern North America, isostasy is probably perfect, i. e., that land and sea bottom are here in a state of hydrostatic equilibrium so delicately adjusted that any transfer of load produces a quantitatively equivalent deformation."‡

While coast stations have in general shown less apparent irregularity in the force of gravity than is often found in the interior, doubtless because they are situated so near the sea level and are therefore more free from the uncertainties associated with the sea level reduction, still greater discrepancies appear than can be attributed to errors of observation. In the following table are collected the residuals observed minus computed gravity, for the stations on or near the coasts, thus

* The attraction of an extended horizontal plate of rock of average density 31 feet (9·4 meters) thick corresponds to ·001 dyne force of gravity.

† The interesting fact has been recently brought out by an Engineer officer, that a rise of one foot, since 1877, in the level of mean high water in the Gulf of Mexico is indicated by the tidal observations at Port Eads at the delta of the Mississippi. This change would correspond to a subsidence of the land of like amount, but may possibly be accounted for by a local settling near the bench mark.

‡ "The Gulf of Mexico as a Measure of Isostasy," W. J. McGee, this Journal, Sept., 1892, vol. xliv, p 189. The following conclusions are also quoted as bearing on the same subject:

"It appears that the crust, in the form in which it exists, must be in a condition of approximate hydrostatic equilibrium, such that a considerable addition of load will cause any region to sink, or any considerable amount denuded off an area will cause it to rise." "Physics of the Earth's Crust" (2d edition), by Rev. O. Fisher, p. 355.

"It may be laid down as a general rule that where great bodies of sediment have been deposited over extensive areas, their deposition has been accompanied by a subsidence of the whole mass." "On some of the greater Problems of Physical Geology," by Major C. E. Dutton, Phil. Soc. of Washington, vol. xi, p. 55.

far determined in the United States (exclusive of Alaska) and for the two methods of reduction to sea level already mentioned. (— indicates gravity smaller than normal, + greater than normal.)

Summary of gravity residuals for Coast Stations.

Coast.	Station.	Latitude north.	Residuals, observed minus computed g.	
			Bouguer's reduction.	Faye's* reduction.
		° ′	dynes	dynes
North Atlantic	Calais, Maine	45 11	−·021	−·015
	Cambridge, Mass.	42 23	−·009	−·003
	Boston, Mass.	42 22	−·007	−·001
	Hoboken, N. J.	40 44	+·008	+·019
	Princeton, N. J.	40 21	−·038	−·032
	Philadelphia, Pa.	39 57	+·004	+·011
	Baltimore, Md.	39 18	−·034	−·023
	Washington, D. C.	38 53	+·014	+·026
Gulf of Mexico	New Orleans, La.	29 57	−·033	−·033
	Galveston, Texas	29 18	−·035	−·035
North Pacific	Seattle, Wash.	47 36	−·135	−·090
	San Francisco, Cal.	37 47	−·016	−·049

The variations in these residuals, while not considerable except in a single case (Seattle), are nevertheless of much interest. It will be noted that with either method of reduction the largest excess of gravity appears at Washington.†

A computation of the amount of flattening of the earth has been made from the 33 results for gravity obtained in the United States in 1894 and 1895. These observations are of course not well suited for this purpose except in combination with results in other parts of the world, as the work of 1894 was intended to develop the effect of elevation and continental position, and not the variation of gravity with latitude, and for this reason those stations differed little in latitude, and even with the few southern and northern stations added during the past season the extreme range in latitude is less than 18° (from 27° 30′ to 45° 11′). Nevertheless it is of interest to see how

* Some slight differences in the last column of this table from values previously given, are due to revised estimates of average elevation. The results from Hoboken, Baltimore, Seattle and San Francisco are from earlier determinations.

† Commandant Defforges, comparing results obtained on the shores of various oceans came to the conclusion that each ocean possesses a characteristic anomaly in the force of gravity along its shores. "Memorial du Dépôt Général de la Guerre, Observations du Pendule," vol. xv, p. 194.

reliable a value can be obtained from such meager data, derived entirely within the borders of the United States. The values reduced to sea level by Faye's reduction were used, and to simplify the computation were averaged together for each degree of latitude. Conditional equations were formed of the form $g_\phi = x + y \sin^2 \varphi$, representing the variation of gravity with latitude, where x is gravity at the equator, y is the difference between gravity at the pole and the equator, and g_ϕ is observed gravity at latitude φ; x and y were then computed by the method of least squares, and substituted in Clairant's theorem. Using Helmert's expansion of Clairant's theorem,* the value $\frac{1}{300.0}$ was obtained for the amount of flattening, or the difference between the earth's polar and equatorial axes divided by the equatorial axis.† Helmert in 1884 obtained the value $\frac{1}{299.3}$ from a discussion of pendulum observations in various parts of the world, and Clarke from a similar discussion in 1880 obtained $\frac{1}{293.2}$. Two of the most important values obtained from arc measurements are those of Bessel (1841) $\frac{1}{299.2}$, and Clarke (1880) $\frac{1}{293.5}$. A variation of one unit in the denominator of these ratios corresponds to a change in the difference between the earth's major and minor axes, of about 481 feet (147 meters), and from the discrepancies in the above and other results one may judge that the actual uncertainty may be nearly a mile.‡ The value derived from the pendulum observations in the United States is not very different from Helmert's and Bessel's, but it is of significance only in showing that a fairly accordant result may be obtained from so few observations very narrowly distributed in latitude, and in further confirming the validity of the reduction to the sea level tentatively employed, and the theory of the condition of the earth's crust on which that reduction is based, the equilibrium or isostatic theory.§ This result has been obtained by combining observations made at altitudes above sea level ranging from 6 ft. to 14085 ft. (2 m. to 4293 m.), and in a great variety of continental locations.

* "Geodasie," by F. R. Helmert, vol. ii, p. 83.

† A result for the flattening of $\frac{1}{296}$ was obtained by comparing the four southern stations, Austin, Laredo, Galveston and New Orleans, with four stations in nearly the same longitude near the 39th parallel in the central plains, St. Louis, Kansas City, Ellsworth and Wallace.

‡ Prof. Harkness says: "Indeed the facts thus far advanced scarcely warrant any conclusion more definite than that the flattening probably lies between $\frac{1}{296}$ and $\frac{1}{306}$, but we shall see presently that there is some further evidence which tends in the direction of the smaller limit" [$\frac{1}{300}$].—"The Solar Parallax and its Related Constants," p. 103.

§ For discussions of the relation of the Coast and Geodetic Survey pendulum observations to these theories, see papers by Mr. G. K. Gilbert, Bulletin Phil. Society of Washington, vol. xiii, p. 61; by Rev. O. Fisher, Nature, vol. lii, p. 433, Sept. 5, 1895; and by M. Faye, Comptes Rendus de l'Académie des Sciences, 20 May, 1895.

Art. XX.—*On Trinidad Pitch;* by S. F. Peckham and Laura A Linton.

The bitumen found on the Island of Trinidad in the so-called Pitch Lake and in its neighborhood, has entered commerce under the name of Trinidad Pitch. That which is found within the lake is called "Lake Pitch;" that found outside the lake is called "Land Pitch."

As it occurs it is a unique substance found nowhere else in nature. It consists of a mixture of bitumen, water, sand, decayed vegetation and gas in such definite proportions that within certain limits the composition of the entire mass is uniform. The bitumen has never yet been investigated in such manner as to determine its relations to other bitumens, but it appears to be of vegetable origin and convertible into solid asphaltum by processes of nature. In its natural condition about one-third of it is water. Deprived of water it is about one-third sand. When the bitumen is dissolved away from the sand under the microscope, the silica appears to be in exceedingly minute amorphous particles from $\frac{1}{10000}$ to $\frac{1}{1000}$ of an inch in thickness. When freed from organic matter by burning, the silica appears in small sharply angular grains, stained by iron and a small quantity of bluish clay. The organic matter not bitumen consists of fragments of vegetation and disorganized cellular tissue, with products of the decomposition of wood.

As the bitumen rises in the center of the so-called lake it is inflated with gas. When the masses are broken into the structure resembles vesicular lava. The gas cavities are of all sizes, some of them very large and in the aggregate occupy at a rough estimate from one-third to one-half the volume of the pitch. At any point in the deposit removed from the center of the lake, the gas, in part, has escaped from the asphaltum and the mass become more compact. Both within and without the lake the pitch is saturated with water. It is in this condition without viscosity and can be trodden upon or squeezed in the hands without adhesion to either hands or feet. In this condition it cuts like cheese, hence the name, "cheese pitch." When freshly dug the color is brown, but if left in the sun it soon darkens, finally becoming a bluish-black. If a mass of any considerable size is laid in the sun, it will melt to a thin pellicle upon the exposed surface, and retain the larger part of the water at a temperature sufficient to remove every trace of water if it were dried in the shade. A mass exposed to the air out of the sun, immediately begins to dry out and

in a short time loses nearly all of the water, which is in part readily re-absorbed if again exposed to dampness.

The evaporation of the water precipitates within the pitch a small percentage of saline matter, chiefly sulphates of the alkalies and alkaline earths, that the natural water holds in solution. The hygroscopic property of the pitch is no doubt largely due to the presence of these salts.

In selecting specimens that would fairly represent the character of the mass of pitch both within and without the lake, we were largely governed by the appearance of the pitch and the relation of the several localities to one another and the center of the lake.

No. 1 was picked up at random from the pitch taken from an excavation from which the cargo of the bark "Ella" was dug, during February and March, 1895. The excavation was upon a village lot about three-quarters of a mile from the lake towards Point La Brea.

No. 2 is from a village lot which we have named the "Photograph Lot." It was here that a pit was dug and photographs taken of the pit at intervals of ten days to determine whether any movement in the pitch was in progress by which a cavity dug in the pitch would refill. No. 2 was taken from the pitch removed from the pit. This lot had been excavated about six months previous and had nearly refilled, and was then being uncovered preparatory to the removal of a fresh supply of several thousand tons. It was about twenty rods nearer Point La Brea than No. 1.

No. 3 is so-called "Iron pitch" from the Photograph lot. This is pitch that has been melted and deprived of its water and gas. It is solid, of a bluish-black color, with a dull earthy fracture and is slightly sonorous when struck.

No. 4 was taken from a lot on the right hand side of the road approaching the lake, that was being excavated by Mr. Ghent. It came from a point 10 or 15 feet below the surface on the western border of the mass filling the ravine down which the overflow of pitch from the lake has taken place, and nearly on the opposite side of the road from the point from which No. 10 was taken.

No. 5 is No. 4, boiled to form Èpureè, in Mr. Ghent's boiling works near Point La Brea.

Nos. 6 and 7 were from opposite corners of a mass about 12 inches square and four inches in thickness. This mass was taken from a point on the northeast side of the lake on the outside of and near to the tramway, and was selected of convenient size from among a quantity that had been broken with a pick preparatory to removal in the tram cars or carts by the Trinidad Asphalt Co.

No. 8 is from an average from the same piece made up by breaking fragments from many points upon its surface.

No. 9 is from the center of the lake or near it. The mass was soft enough to flatten in the shade, but did not stick to the paper in which it was wrapped. After drying it became ridged and brittle.

No. 10 is an average from a large piece taken from an excavation being made by the Trinidad Asphalt Co. on the Bellevue estate near the road leading to the lake. The excavation extended along the road for perhaps 1500 feet and was narrow. The pitch was clean and pure but was covered by rank vegetation that grew upon and in the pitch itself, and not upon soil that covered it. This fact accounts for the high percentage of organic matter not bitumen, although the piece was taken several feet below the surface.

No. 11 is a decomposition product of the pitch from the photograph lot.

No. 12 is another decomposition product from the same lot. It resembled coke and may have been heated. It is the only material resembling coke that we saw in or around the lake and the amount was only a few pounds.

No. 13 is also a decomposition product resembling No. 11, from the south side of the lake. It was enclosed by a pellicle of sun-dried, melted pitch, within which it was of a light brown color with a columnar structure, like starch, and was very easily powdered. It had the external appearance of asphaltene that had been precipitated from solution.

No. 14 is from a pile of land pitch melting on the beach at Point La Brea, said to have come from the same lot as No. 1.

No. 15 was brought from the lake about 1865, by the late William Attwood of Portland, Me.

No. 16 is from the southeast side of the lake inside the road and was cut from the surface at a spot free from vegetation. The point was about half way from the tramway to the border of the lake.

No. 17 is from the west side about mid-way of the tramway loop, where men were loading tram cars. It was picked up from under the feet of the men.

No. 18 is iron pitch from the northeast side of the lake near where the left limb of the tramway, looking south, enters upon the lake.

No. 19 is refined land pitch, from the refinery of the Trinidad Bituminous Asphalt Co. at Jersey City, N. J. It came from the same lot as No. 2.

No. 20 is refined lake pitch, purchased in New York of the Warren, Scharf Co.

No. 21 is from the northeast side of the lake near the left limb of the tramway looking south.

No. 22 is from the northeast side of the lake near the right of the left limb of the tramway loop looking south, about one hundred feet from No. 21.

No. 23 is from the northwest side of the lake on the west side of the right limb of the tramway loop looking south.

No. 24 is from the south side of the lake near where the road leaves the lake.

No. 25 is from the northwest side of the lake on the west side of right loop of tramway looking south near a "blow-hole."

No. 26 is from the south side of the lake near where the road leaves it, about one hundred feet from No. 24.

No. 27 is Èpureè from the boiling works of the Trinidad Asphalt Co., at Point La Brea. It was made by boiling a mixture of No. 10, No. 8 and No. 9.

Nos. 6, 7, 8, 9 and 17 represent commercial lake pitch.

Nos. 16, 21, 22, 23, 24, 25 and 26 represent the contents of the lake occupying the annular space outside the tramway and embracing hundreds of thousands of tons. The area is about 60 per cent. of the surface of the lake.

Nos. 1, 2, 4, 10 and 14 represent an average of commercial land pitch.

Nos. 5 and 19 represent refined land pitch.

Nos. 20 and 27 represent refined lake pitch.

Nos. 3, 11, 12, 13 and 18 are rubbish so far as commerce is concerned, and are introduced here to show that there is rubbish in the lake as well as outside of it, and also the relation of alteration products to the commercial pitch.

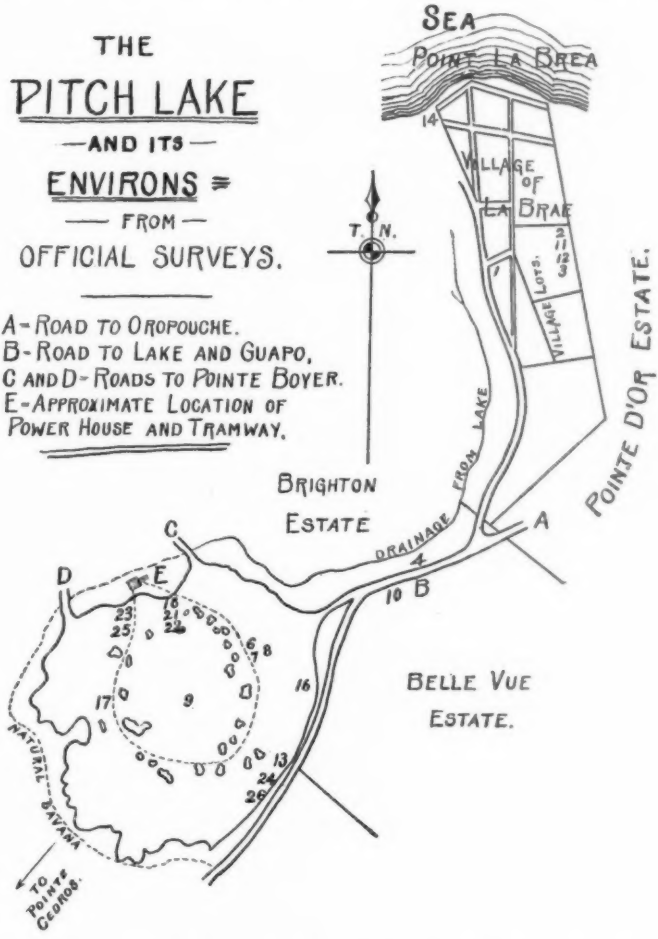
The locations of the several specimens are shown on the accompanying map.

No specimens were taken from near the border of the west side of the lake, because the pools of water were so wide as to make it quite difficult to get around among them. These specimens are believed to furnish a fair representation of the pitch as it occurs both within and without the so-called lake, and also the refined pitch and Èpureè made from the same.

As before stated, the condition of the pitch in the entire deposit is that of complete saturation with water. Water is reached everywhere within a few feet of the surface and often stands in the areas from which pitch has been excavated. Both outside and upon the borders of the lake it appears to render the re-filling of the areas less rapid. In and near the center of the lake, the enormous volume of gas constantly rising, forces the pitch into any excavation more rapidly.

The pitch is removed from near the tramway soon after it is dug, and before it has time to melt is weighed full of water

and immediately thrown into the hold of the ship. The pitch from other parts of the deposit is dug up in large pieces and removed in carts to the beach, where it is immediately put into lighters and transferred as soon as possible to the hold of the



ship anchored off shore. In either case the pitch reaches the hold of the ship containing from 25 per cent to 30 per cent of water and considerable gas, especially that removed from the lake. Before being discharged, heat, the motion of the ship

and the weight of the mass upon itself have rendered the mass within the hold of the ship nearly solid and the material is no longer the natural crude pitch, but something more or less removed from it by loss of water and gas.

In the case of samples like those taken by ourselves and packed in a trunk, labelled and carefully wrapped in paper, the loss of water was nearly complete before they reached New York. In fact it required only a week or ten days in Port of Spain to completely transform the cheese pitch from a moist, porous substance, cutting with a knife like cheese, to a hard brittle solid, readily broken into fragments that could only be cut with considerable difficulty, provided it was kept out of the sun. It is therefore manifest that commercial samples of crude pitch are not samples of natural crude pitch; nor is it possible to bring away from Trinidad samples of "cheese" pitch in the natural condition. We therefore determined to analyze the specimens selected free from water and gas, and thus render the results comparable.

The samples were severally coarsely powdered and air dried by placing them upon the laboratory table in the sun. In dry weather they soon dried to a constant weight. In damp weather they lost and gained within narrow limits indefinitely. Heated in an air bath to 50° C., they were soon brought to a constant weight. Heated at 100° C., to a constant weight, a varying loss of volatile oils invariably followed, which showed that determinations of water at 100° C. as a constituent of the pitch leads to vitiated results from two sources: first, the percentage of water is not constant in the same specimen but varies with the condition of the atmosphere; second, pitch that is apparently very dry gives off an appreciable amount of volatile oils below 100° C. The samples were therefore dried to a constant weight, at a temperature below 50° C. Of course, if, for any reason, the amount of water in a given specimen of pitch is desired, it is easily ascertained, but it should not be reported as a constituent of the pitch, as the varying percentage of water causes all of the other percentages to vary in the same specimen at different times.

The dried specimens were then exhausted with petroleum ether. In the present instance the petroleum ether used for all the specimens came from the same barrel and was of specific gravity 74° B. The exhausted residues were dried at 100° C. and the difference in weight was computed as petrolene. The dried residues were then exhausted with boiling spirits of turpentine, washed with ethyl alcohol and dried at 100° C. to a constant weight. The loss was noted. The dried residues were then exhausted with chloroform and dried and the loss noted. The loss by turpentine plus the loss by chloroform is

estimated as asphaltene. The distinction made by the use of these two solvents will be noted farther on. The dried residue from the chloroform exhaustion was then put into a platinum crucible and the organic matter burned off. The residue was inorganic or mineral matter, sand, and the small percentage of soluble and non-volatile salts present. The pitch was thus divided into that portion soluble only in petroleum ether, or "petrolene," that portion soluble only in boiling spirits of turpentine, and chloroform which together form "asphaltene," and with the petrolene constitutes the "total bitumen"; also the "organic matter not bitumen" and the "inorganic matter."

Table No. 1 represents the results of the analysis of the 27 specimens described above. Any attempt to classify them as to the locality from which they were obtained by means of these analyses will inevitably fail. Our analyses prove that an average of specimens will show an increase in the proportion of "mineral matter" and of "organic matter not bitumen," as the point from which the specimen is taken is removed from the center of the lake; yet, the exceptions to this rule are so numerous and marked, that no certainty can attach to the use of these criteria.

Great value is attached by some experts on asphaltum to the determination of the specific gravity and temperature at which the different specimens soften and flow. These tests might have some value if applied to a pure bitumen which had been proved to change in specific gravity, etc., as it underwent chemical and other changes; but no such investigation and proof in relation to any asphaltum has been attempted. Such a relation has been assumed but not proved. The fact that Trinidad pitch is a mixture so indefinite that it is almost, if not quite impossible, to select two pieces that have the same proportions (as is proved by Nos. 6, 7 and 8) is a sufficient reason why no such distinctions can be based upon such determinations. The average proportions of mineral matter to bitumen in the 5 samples of commercial lake pitch taken from near the center of the lake is 100 : 151. No two of them are exactly alike, and the extremes are, lowest 100 : 148, highest 100 : 155. The seven specimens from outside the tramway show greater uniformity, yet no two are alike and all are below the lowest of the five mentioned above. The average ratio of the land pitch is still a little lower, while the extremes of variation are 134 and 146. It is manifest that between these extremes of proportion of 100 : 134 and 100 : 155 a marked variation in specific gravity and flowing test must occur, as the sand is about twice as heavy as the bitumen. These extremes of variation include one-sixth of the average amount of bitumen present.

These observations apply with equal force to the ingredient of the mixture denominated "organic matter not bitumen." In the five specimens of commercial lake pitch the average amount of this material is 10·651 per cent. The extremes of variation include 1·482 per cent, which is 14·8 per cent or nearly one-sixth of the average amount present. The smallest amount is found in the average pitch from near the center of the lake, yet No. 17, which was picked up from under the feet of the men who were loading the tram cars on the west side of the tramway near the middle, contains nearly 12 per cent. This average lake pitch is found where the mass is in constant motion from escape of gas. Here there is no organic matter added by vegetation to the amount originally found in the pitch. The growth of vegetation upon and in the pitch itself is the source from which the excess of organic matter found in the lake pitch taken from points outside the center and from the so-called land deposits is derived. As this excess consists mainly of coarse roots it is removed by refining, so that when the pitch is ready for use the difference in the organic matter has largely or entirely disappeared. See numbers 2 and 19, 8 and 20.

Table No. 2 shows the results of a comparative examination of the bitumen contained in the different samples without regard to the amount present. The first division of this table shows the percentage of the crude pitch dissolved only by petroleum ether, boiling spirits of turpentine and chloroform respectively. The middle column gives the percentage of the total bitumen in the crude pitch. The next three columns give the percentages of the total bitumen present dissolved only by petroleum ether, boiling spirits of turpentine and chloroform respectively. The last column shows the percentage of the total bitumen dissolved by boiling spirits of turpentine. This item is represented by adding together the items of the first and second columns, as all of the material that is dissolved by petroleum ether is soluble in boiling spirits of turpentine. A comparison of these numbers along each horizontal line shows that there is no necessary connection between the amount of *crude pitch* dissolved by petroleum ether and the *quality* of the total bitumen. As an example, in No. 1, which is a land pitch, 100 parts of bitumen are mixed with very nearly 100 parts of sand and organic matter, not bitumen, while in No. 9 from the center of the lake 100 parts of bitumen are mixed with about 92 parts of foreign matter. Now while the percentage of crude pitch dissolved by petroleum ether from No. 1 is 2·333 per cent less than the percentage of No. 9 dissolved by the same menstruum, the *proportions* of the total bitumen dissolved in the two cases are almost identical,

viz: 66·5 per cent and 66·544 per cent. Again, No. 17 was broken off a piece of pitch as a negro raised it and threw it into a tram car. It fell under his feet and was secured as a piece of convenient size for a specimen. On analysis it gave 34·2 per cent soluble in petroleum ether, while the total bitumen was 52·997 per cent. These results give 64·531 per cent of the total bitumen soluble in petroleum ether and 89·372 per cent soluble in boiling spirits of turpentine. Of the five samples of commercial land pitch, Nos. 2, 4 and 10 contain 33·62, 33·736 and 33·730 per cent of matter soluble in petroleum ether. The average is 33·705, yet the average per cent of the total bitumen present soluble in petroleum ether is 64·283 per cent, almost identically the same as that yielded by No. 17. In fact No. 2 and No. 17 represent the extremes of location from the west side of the tramway to the village lot furthest from the lake and the difference in the percentage of the total amount of bitumen soluble in petroleum ether is only (·255 per cent) two hundred and fifty-five thousandths of one per cent—a difference wholly without significance. No. 9 was from the center of the lake and No. 1 from a village lot about 20 rods nearer the lake than No. 2, yet the difference in the amount of total bitumen present soluble only in petroleum ether, is only forty-four thousandths of one per cent. Arranged in a table these samples of commercial pitch appear as follows:

No. 1.	Land	66·500
No. 9.	Lake (center)	66·544
No. 2.	Land	
No. 4.	Land	
No. 10.	Land	
	Average	64·283
No. 17.	Lake	64·531

Of the specimens representing the pitch filling the annular space outside the tramway and beyond, to the boundaries of the lake, Nos. 21 and 22 were taken from the bottom of an excavation on the right of the left limb of the tramway loop as it descends upon the lake and within 140 feet of each other. Nos. 23 and 25 were taken from points very near each other on the right or west side, of the right limb of the tramway loop. These four points are on the north side of the lake and near the border. No. 16 was taken from a point on the southeast side of the lake about half way from the tramway to the border of the lake. The spot was free from grass, yet it was within the area covered with vegetation. Nos. 24 and 26 were from points on the south side of the lake directly opposite Nos. 21, 22, 23 and 25 and about 100 feet apart.

The percentage of total bitumen soluble in petroleum ether is shown in the following table:

No. 21	51·555
" 22	65·809
" 23	64·960
" 24	62·974
" 25	68·431
" 26	70·691
" 16	66·933

Nos. 25 and 26 from opposite sides of the lake and very near the border, are the highest in the list and higher than No. 9 from the center of the lake, and higher than No. 6 which is the highest commercial lake pitch. The differences and identities of these different groups, as well as between the individual members of the groups, can be readily traced by reference to table No. 2.

The portion soluble in petroleum ether is called "petrolene." It is a constituent and essential part of the pitch, and embraces all that is most volatile in the pitch, including those etherial or oily fluids that are given off at a temperature below the boiling point of water, and which are found in all specimens from all parts of the deposit (land and lake) that have not been previously heated or decomposed. It is contended that petrolene is the cementitious portion of the pitch, because the remaining portion of the bitumen is solid and insoluble in residuum oil. It might just as well be contended that water is the cementitious principle of glue and that glue has no cementing properties because it is not soluble in alcohol. The fact is, that the bitumen of Trinidad pitch consists of asphaltene dissolved in petrolene and that its cementitiousness is just as much due to one as the other. Sand cannot be cemented with either petrolene or asphaltene alone, neither can wood be cemented with either water or glue alone. The cementitiousness of the pitch depends upon the amount and quality of the bitumen present.

What meaning is intended to be given the word "dry" in connection with pitch is not very clear. It cannot be freedom from moisture, for no specimen of crude pitch is entirely free from water. As found in the deposit, the pitch both outside and inside the lake is saturated with water, and its condition after removal from the deposit depends entirely upon what is done with it. The use of the word "dry" appears to imply that the pitch from outside the lake has lost the whole or a large part of the most volatile oils originally contained in it. No proof whatever has been offered to sustain such assertions. It has been contended that the sun heats the land pitch to

140°–150° F. Outside the lake the deposit is covered with from 2 to 15 feet of earth, rubbish and vegetation. The large area in the center of the lake from which, for convenience, the commercial lake pitch is removed, is bare and black, exposed to the full rays of the tropical sun. Shallow pools of water on the surface of the lake appear to have a temperature of about 100° F. The pitch is probably hotter. It is therefore reasonable to suppose that if evaporation of light oils were taking place that the pitch in the lake would be "driest." Our examination has shown us that both land and lake pitch contain oils volatile under the boiling point of water in about the same proportion; small in both cases.

The use of both turpentine and chloroform as solvents for asphaltene is based upon observations made a year ago upon the methods employed for the technical analysis of asphaltum. Is was found that in the United States carbon disulphide has been almost exclusively used as a solvent for asphaltene, while in Europe spirits of turpentine has been used for the same purpose. Careful experiment showed that neither of these solvents would dissolve all of the bitumen from the specimens in our possession, among which were those from the valley of the Rhone. It was observed that turpentine left a large and varying residuum when applied to nearly all of the American specimens, including Trinidad, and that only a very small percentage was left from the Rhone specimens and those from the Indian Territory. It was also found that in either case chloroform alone effected a complete extraction of the bitumen. Later we received a specimen of Neufchatel asphaltic rock from which turpentine completely dissolved the bitumen. This led to an examination and classification of the various bitumens with reference to the action of turpentine. It was found that a large percentage of the asphaltene of Grahamite and a varying percentage of the asphaltene of Trinidad pitch and the asphaltums of California is insoluble in turpentine. It was also found that the asphaltene of the bitumens of Texas and the valley of the Rhone is almost wholly soluble in turpentine, and further that when the bitumen is removed from solution from these asphaltic rocks it is not a solid asphaltum but a semi-solid viscous fiuid, that does not become solid by exposure, but has remarkable stability in the atmosphere. These facts lead to the belief that the proportion of asphaltum soluble only in chloroform furnishes an indication of the extent to which a bitumen has been affected by "aging."

It has been asserted that land pitch had matured through geological time and reached a condition approaching "glance pitch." The word glance as applied to pitch has nothing to do with its age, or with any other property except its appear-

ance. The word glance is from the German word "glanz," which means glistening. Pure asphaltum that has been melted has a smooth glistening fracture like rosin or anthracite coal. It would be impossible to produce glance pitch by melting a material containing so much mineral matter as Trinidad pitch. Iron pitch is the nearest approach to it that can be found in the neighborhood of the Pitch lake, and that was found both within and without the lake. If it has been intended to convey the impression that asphaltum becomes glance pitch by aging, and that the land pitch is farther on the way through geological time towards glance pitch than that in the lake, it must also be admitted that so far as anyone knows to the contrary the whole phenomenon of the pitch lake may have been produced within five hundred years. Our analyses have not furnished the slightest evidence that the bulk of the pitch outside the lake has aged any more than that within it. Our analyses also show that the bulk of the pitch is in good condition throughout the deposit; and that the effects of aging are about equally distributed.

These analyses do not sustain the allegation that land pitch is any less uniform in composition than lake pitch. The following figures represent the extremes in the percentage composition of total bitumen in the five samples of commercial lake pitch and the five samples of commercial land pitch soluble in

	Land.	Lake.
Petroleum ether	3·445%	3·601
Boiling spirits turpentine	9·746%	7·110
Chloroform	9·622%	9·716
Total soluble in turpentine	9·621%	9·696

The correspondence between them is remarkable.

It makes no difference whether these results of analysis are taken as a whole, or compared severally, or in the different elements that make up each analysis, the same conclusion is inevitable, viz: that the entire deposit both within and without the boundaries of the lake is one and the same substance and in substantially the same condition.

There are five specimens in the collection that represent the rubbish of the deposit. Nos. 3 and 18 are respectively land and lake "iron-pitch," Nos. 11 and 13 are decomposition products from the land and lake respectively, that may be what has been called "chocolate pitch," No. 12 may be what has been called "grey pitch." None of these are commercial articles, yet they are shown by these analyses to have scientific relations to the commercial pitches full of interest. By comparing these five specimens with any other five in the tables, it will be found that they are low in material soluble in petro-

leum ether; high in material soluble in boiling spirits of turpentine and chloroform, and at the same time they are low in the percentage of total bitumen soluble in boiling spirits of turpentine. This apparent contradiction is easily accounted for when the high percentage of material soluble only in chloroform is observed. The proper interpretation of these results in reference to the aging of asphalt awaits the completion of investigations now in progress.

TABLE No. 1.—*Analyses of Trinidad Pitch.*

No.	Petrolene.		Asphaltene.		Total Bitumen.	Organic Not Bitumen.		Inorganic.	
a.	33·600		17·150			11·625		37·625	
b.	33·635		17·200			11·850		37·300	
1. Mean		33·617		17·175	50·791		11·737		37·462
a.	33·640		18·888			11·347		36·123	
b.	33·600		18·468			11·652		36·280	
2. Mean		33·620		18·678	52·297		11·499		36·201
a.	33·637		23 621			7·840		34·902	
b.	33·511		23·034			8 988		34·467	
3. Mean		33·574		23·327	56·901		8·414		34·684
a.	33·769		18·764			10·564		36·903	
b.	33·703		18·498			11·138		36·555	
4. Mean		33·736		18·631	52·367		10·851		36·729
a.	33·600		18·000			10·500		37·900	
b.	33·650		18·500			9 800		38·050	
5. Mean		33·625		18·250	51·875		10·150		37·975
a.	36·650		17·200			10·800		35·350	
b.	36·650		17·250			10·775		35·325	
6. Mean		36·650		17·225	53·875		10·787		35·337
a.	36·392		17·151			10·491		35·961	
b.	36·392		17·245			10·410		35·990	
7. Mean		36·372		17·198	53·570		10·450		35·975
a.	36·300		17·975			9·900		35·725	
b.	36 650		17·800			9·850		35·700	
8. Mean		36·475		17·887	54·362		9·875		35·712
a.	35·950		18·050			10·875		35·125	
b.	35·950		18·100			10·690		35·260	
9. Mean		35·950		18·075	54·025		10·782		35·192
a.	33·730		18·948			11·390		35·930	
b.	33·730		18·750			11·667		35·842	
10. Mean		33·730		18·849	52·579		11·528		35·886
a.	21·200		30·375			9·600		38·500	
b.	21·525		30·250			10·100		38·450	
11. Mean		21·362		30·312	51·674		9·850		38·475
a.	0 000		3·000			43·525		53·475	
b.	0·000		3·000			43·550		53·450	

No.	Petrolene.	Asphaltene.	Total Bitumen.	Organic Not Bitumen.	Inorganic.
12. Mean	0·000	3·000	3·000	43·537	53·462
a.	19·200	33·050		9·650	38·000
b.	19·300	33·575		9·475	37·750
13. Mean	19·250	33·312	52·562	9·562	37·875
a.	31·800	18·725		11·925	37·550
b.	31·750	18·525		12·355	37·370
14. Mean	31·775	18·625	50·400	12·140	37·460
a.	32·176	43·649		5·570	18·605
b.	32·450	43·360		5·960	18·290
15. Mean	32·313	43·474	75·787	5·765	18·447
a.	35·375	17·475		11·000	36·150
b.	35·425	17·600		10·925	36·050
16. Mean	35·400	17·537	52·987	10·962	36·100
a.	34·200	18·775		11·275	35·750
b.	34·200	18 820		11·440	35·540
17. Mean	34·200	18·797	52·997	11·357	35·645
a.	22·275	22·225		8·925	46·575
b.	22·225	22·475		8·950	46·350
18. Mean	22·250	22·350	44·600	8·937	46·462
a.	39·350	17·175		9·225	34·250
b.	39·300	17·400		9·100	34·200
19. Mean	39·325	17·287	56·612	9·162	34·225
a.	38·150	18·750		8·100	35·000
b.	38·125	18·921		7·923	35·031
20. Mean	38·137	18·835	56·973	8·011	35·015
a.	26·925	25·325		11·375	36·375
b.	26·925	25·275		11·100	36·700
21. Mean	26·925	25·300	52·225	11·237	36·537
a.	34·750	18·035		10·970	36·245
b.	34·700	18·050		10·875	36·375
22. Mean	34·725	18·042	52·767	10·922	36·310
a.	34·400	18·550		11·500	35·550
b.	34·425	18·575		11·325	35·675
23. Mean	34·412	18·562	52·974	11·412	35·612
a.	33·275	19·325		11·100	36·300
b.	33·100	19·700		11·150	36·050
24. Mean	33·187	19·572	52·699	11·125	36·175
a.	34·950	16·100		10·600	38·350
b.	34·850	16·100		10·475	38·575
25. Mean	34·900	16·100	51·000	10·537	38·462
a.	35·600	14·650		11·100	38·650
b.	35·125	14·675		11·325	38·875
26. Mean	35·362	14·662	50·024	11·212	38·762
a.	34·725	20·175		8·425	36·675
b.	34·775	19·625		8·925	36·675
27. Mean	34·750	19·900	54·650	8 675	36·675

TABLE No. 2.—*Analyses of Trinidad Pitch.*

No.	Percentage of Crude Pitch only soluble in			Total Bitumen.	Percentage of Total Bitumen only soluble in			
	Petroleum Ether.	Boiling Spts. Turpentine.	Chloroform.		Petroleum Ether.	Boiling Spts. Turpentine.	Chloroform.	Total in S. Tur.
1.	33·617	10·887	6·287	50·791	66·500	21·250	12·250	87·750
2.	33·620	10·494	8·183	52·297	64·276	20·066	15·658	84·342
3.	33·574	13·802	9·819	57·195	58·702	24·131	17·167	82·833
4.	33·736	10·511	8·120	52·367	64·422	20·071	15·506	84·493
5.	33·625	15·575	2·675	51·875	64·819	30·022	5·159	94·841
6.	36·650	12·800	4·425	53·875	68·132	23·700	8·168	91·832
7.	36 372	11·683	5·514	53 570	67·896	21·862	10·242	89·758
8.	36·475	15·750	2·137	54·362	67·096	28·972	3·932	96·068
9.	35·950	12·310	5·762	54·022	66·544	22·788	10·668	89·332
10.	33·730	15·670	3·179	52·579	64·151	29·812	6·036	93·963
11.	21·362	15·200	15·112	51·674	41·340	29·415	29·245	70·755
12.		1·700	1·300	3·000	Alteration Product			
13.	19·250	20·487	12·825	52·562	36·621	38·976	24·403	75·597
14.	31·775	11·875	6·750	50·400	63·055	23·547	13·398	86·602
15.	32·313	21·249	22·225	75·787	42·636	28·038	29·326	70·674
16.	35·400	12·300	5·237	52·937	66·935	23·162	9·903	90·097
17.	34·200	11·575	7·222	52·997	64·531	21·841	13 648	86 372
18.	22·250	9·735	12·615	44·600	49·921	21·837	28·252	71·758
19.	39·325	11·285	6·002	56·612	69·465	19·933	10·602	89·398
20.	38·137	12·538	6·297	56·973	66 959	22·016	11·025	88·975
21.	26·925	18·612	6·687	52·224	51·555	35·640	12·805	87·195
22.	34·725	13·175	4·867	52·767	65·809	24·968	9·223	90·777
23.	34·412	13·100	5·462	52·974	64·960	24·720	10·320	89·680
24.	33·137	14·237	5·275	52·699	62·974	27·016	10·010	89·990
25.	34·900	9·200	6·900	51·000	68·431	18·039	13·530	86·470
26.	35·362	9·862	4·800	50·024	70·691	19·714	9·595	90·405
27.	34·750	10·712	9·187	54·650	63·526	19·592	16·882	83·118

University of Michigan,
Ann Arbor, Michigan, November 30, 1895.

ART. XXI.—*A Meteorite from Forsyth Co., North Carolina;* by E. A. DE SCHWEINITZ, M.D., PH.D.

ABOUT three years ago there was ploughed up on a farm in the southwestern portion of Forsyth Co., a mass about 50 lbs. in weight which, upon cursory examination, appeared to be pure iron, probably of meteoric origin. The mass had an irregular wedge-like shape and was covered with a thin scale of oxide of iron. The metal beneath was exceedingly tough, could be cut with the greatest difficulty, and fragments obtained by means of chipping with a cold chisel showed a crystalline structure. A polished surface etched with nitric acid did not show the Widmanstätten figures distinctly, but a mottled crystalline structure. The appearance of the meteorite when found can be seen from the accompanying figures, 1 to 4 (one-fourth natural size). Subsequently, two slices were cut from the meteorite and etched respectively with nitric and hydrochloric acids, without producing any very characteristic markings.

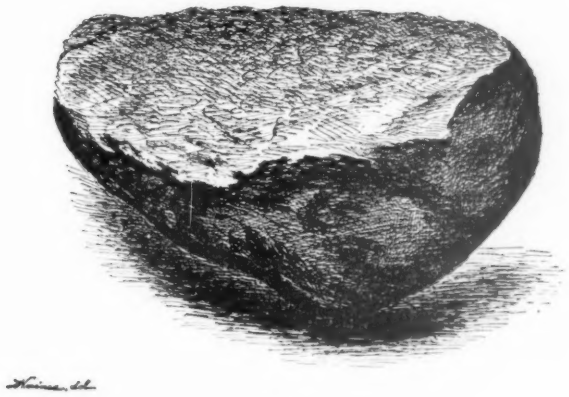
A preliminary analysis made from a piece chipped off the end of the meteorite by means of a cold chisel gave the following results:

Fe	94·90	per cent.
S	·22	"
Ni	4·18	"
Co	·33	"
P	trace	

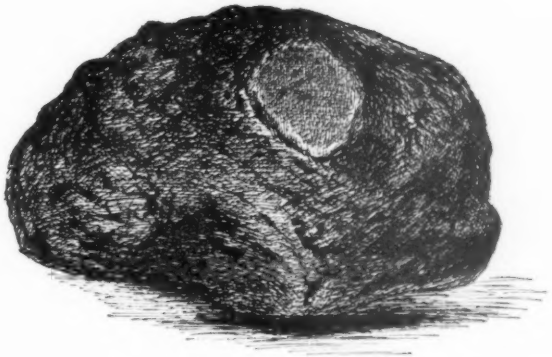
From this it would seem to be closely allied to the Guilford County meteorite, possibly a chip of the same find. This iron is now in the possession of Mr. G. F. Kunz of New York.

Biochemic Laboratory, Columbian University,
Washington, D. C., November 30, 1895.

1.



2.



3.

4.

ART. XXII.—*On a new Alkali Hornblende and a titaniferous Andradite from the Nepheline-Syenite of Dungannon, Hastings County, Ontario;* by FRANK D. ADAMS and B. J. HARRINGTON, McGill College, Montreal.

IN a paper which appeared in the number of this Journal for July, 1894, the discovery of a large area of nepheline-syenite in the township of Dungannon, in the Province of Ontario, was announced and the geological relations and mineralogical characters of the mass briefly described.

One of the many peculiarities of this rock is the absence from it of the mineral pyroxene, which is usually the chief iron-magnesia constituent in rocks of this class, its place being taken by hornblende and mica, but even these minerals are present in comparatively small amount. Of the hornblende two varieties, occurring in different parts of the mass, were distinguished. The first, from near the York river, has a large axial angle with strong pleochroism in tints varying from pale yellow to deep green, and although containing a considerable amount of soda, probably approaches common green hornblende in composition. The second variety, which occurs in a series of exposures about two miles to the east of the village of Bancroft, is quite different in character, having a small axial angle with high extinction and a much stronger pleochroism in the bluish tints suggestive of arfvedsonite.

A number of additional thin sections have been prepared and in the present paper the results of a further investigation of the optical properties and chemical composition of this second variety of hornblende are presented.

Hornblende—The mineral occurs in hypidiomorphic grains, which show the usual hornblende cleavages; it is optically negative, a being the acute bisectrix, but the double refraction is weak.

It possesses, as has been mentioned, a strong pleochroism as follows:

$\mathfrak{a}$ = yellowish green. $\mathfrak{b}$ and $\mathfrak{c}$ = deep bluish green.

The absorption is $\mathfrak{c} = \mathfrak{b} > \mathfrak{a}$. $\mathfrak{b}$ and $\mathfrak{c}$, if not quite equal in absorption, are nearly so, hence sections cut at right angles to the acute bisectrix show but little pleochroism and are nearly isotropic. $\mathfrak{c}$ lies nearest the vertical axis, but whether toward the acute angle β or on the opposite side cannot be determined as the mineral does not possess a good crystalline form; it makes with the vertical axis a large angle the extinction amounting to 30°. The plane of the optic axes is the clinopina-

coid, and there is a strong dispersion—red greater than violet. What drew especial attention to this hornblende in the first instance was the fact that it appeared to be nearly uniaxial. When a section, cut at right angles to the acute bisectrix, is examined between crossed nicols in convergent light, a black cross is seen somewhat thickened toward the intersection of the arms. This cross, on revolving the stage, divides into two hyperbolas, but these separate from one another but very little, and appear to separate less than they really do, on account of the fact that the low double refraction and deep color of these sections causes the hyperbolas to be ill-defined, while the whole field is very dark. The dispersion, however, makes itself evident in the varying colors on the sides of the hyperbolas. When, however, a gypsum plate giving a red of the first order is inserted above the objective the hyperbolas become a little better defined, although still not sufficiently definite to allow the axial angle to be accurately measured. The axial angle is found to be over 30°, possibly as much as 45°, which, however, is still very small for hornblende, being about one-half the usual value. Our thanks are due to Professor Rosenbusch for his assistance in working out these optical relations.

On examining a large series of thin sections of nepheline-syenites representing most of the important occurrences hitherto discovered, only two rocks were found which contain a hornblende at all similar to that above described. The first of these is the nepheline-syenite from the Corporation Quarry at Montreal, in which hornblende with the same small axial angle, low double refraction, intense color and pleochroism, large extinction angle and high specific gravity, occurs intergrown with the augite. The second is the hornblende described by Hackman under the name of arfvedsonite and which occurs intergrown with aegerine in the nepheline-syenite from Umptek in the Kola peninsula.* This mineral, however, differs from typical arfvedsonite in having an extinction of about 40° as well as in several other important respects. It possesses moreover a very small axial angle, although this fact is not noted by Hackman, while in true arfvedsonite the axial angle is very large. This Kola hornblende is much lighter in color than the hornblende from either of the above mentioned Canadian localities.

In order to determine the chemical composition of this somewhat remarkable variety of hornblende from the Dungannon rock, it was decided to separate a portion for analysis. A considerable quantity of the rock was accordingly reduced to

* "Petrographische Beschreibung des Nephelinsyenites vom Umptek," von Victor Hackman. Kuopio, 1894, p. 14.

powder and passed through a sieve of 43 meshes to the inch—the rock being rather coarse in grain—and after having been freed from dust was treated with Thoulet's solution, having a specific gravity of 3·13, in a large separating funnel. In this way an almost complete separation of the colored constituents was effected. These latter, which sank in Thoulet's solution, were subjected to the action of a bar magnet and then treated with dilute hydrochloric acid, and various impurities thus removed. The purified powder was then treated first with Klein's solution, having a specific gravity of 3·22, and then with methylene iodide, having a specific gravity of 3·323. In both fluids practically everything sank, only a few composite grains floating. A microscopic examination showed the powder now to consist of grains of hornblende and of garnet with some composite grains consisting partly of nepheline. Further separation became difficult since, as was subsequently ascertained, the hornblende had a specific gravity of 3·433, and the specific gravity of the garnet was 3·739, while many composite grains consisting of garnet and nepheline had a specific gravity practically identical with that of the hornblende. As the electro-magnet was found to be useless, both minerals being readily attracted by it, Retger's silver nitrate method was employed.* The silver nitrate was fused in a properly arranged test tube, and after the introduction of the powder, potassium nitrate in powder was gradually added to the fused mass until the garnet fell, the whole being frequently stirred and maintained at a temperature of from 200° to 240° C. On allowing the mass to solidify, a portion of the powder was found to have collected at the top of the mass, while the rest was at the bottom, the intervening part being quite free from mineral grains. The solid mass was then cut in two and the salts dissolved by treatment with water. After three successive separations the hornblende was obtained quite free from grains of garnet—the only impurities present being some composite grains consisting of garnet and nepheline. This powder was then placed under a lens and all the composite grains picked out by means of a fine needle. In this way a quantity of pure hornblende sufficient for purposes of analysis was obtained, while the garnet was obtained directly in a state of purity without the necessity of a final separation by hand.

Both minerals were found to be quite fresh and bright and quite unacted upon by the fused salts.

The hornblende† was then analyzed by Dr. Harrington with the following results:

* "Ueber Schwere Flussigkeiten zur Trennung von Mineralien." Neues Jahrbuch für Mineralogie, etc., 1889, ii, p. 190.

† We would suggest Hastingsite as a varietal name for this hornblende, connecting it with the region where it occurs.

Silica	34·184
Titanium dioxide	1·527
Alumina	11·517
Ferric oxide	12·621
Ferrous oxide	21·979
Manganous oxide	·629
Lime	9·867
Magnesia	1·353
Potash	2·286
Soda	3·290
Water*	·348
	99·601
Specific gravity	3·433

The atomic and quantivalent ratios deducible from the above analysis are as follows:

	Atomic.		Quantivalent.	
Si	570×4	=2280	2356	2356
Ti	19×4	= 76		
Al	226×3	= 678	1152	2354
Fe^{III}	158×3	= 474		
Fe^{II}	305×2	= 610	1202	
Mn	9×2	= 18		
Ca	176×2	= 352		
Mg	34×2	= 68		
K	48	48		
Na	106	106		

The ratio of $(R_2O+RO) : R_2O_3 : SiO_2$ is 601 : 192 : 589, or approximately 3 : 1 : 3, and obviously the mineral is a true orthosilicate agreeing fairly with the formula $(\overset{I}{R_2}\overset{II}{R})_3\ \overset{III}{R_2}Si_3O_{12}$, or, more fully, $(Fe, Mn, Ca, Mg, K_2, Na_2)_3\,(Fe, Al)_2\,(Si, Ti)_3\,O_{12}$ —a constitution analogous to that of garnet.

So far as we are aware no other hornblende containing so small a proportion of silica has been analyzed; but the small percentage of silica is explained by the large proportions of ferrous and ferric oxides. This is made plain by the following formulæ and the corresponding percentages of silica deduced from them:

Formula.	P. C. of SiO_2.
$3FeO, Fe_2O_3, 3SiO_2$	32·19
$3CaO, Fe_2O_3, 3SiO_2$	35·43
$3FeO, Al_2O_3, 3SiO_2$	36·14
$3Na_2O, Al_2O_3, 3SiO_2$	38·38
$3CaO, Al_2O_3, 3SiO_2$	40·00

* Loss after igniting for about fifteen minutes. On further ignition the powder gained in weight owing to oxidation of the ferrous oxide.

The Dungannon hornblende is interesting in connection with the views of Scharizer, who suggested in 1884* that many of the aluminous hornblendes might be regarded as molecular compounds of the metasilicate actinolite, $Ca(Mg,Fe)_3Si_4O_{12}$, and the orthosilicate $(\overset{I}{R_2}\overset{II}{R})_3\overset{III}{R_2}Si_3O_{12}$, for which he employed the name syntagmatite, originally given by Breithaupt to a black hornblende from Vesuvius. The hornblende from the Island of Jan Mayen, analyzed by Scharizer,† and that from Bohemia, analyzed by Schmidt,‡ agree closely with the so-called "syntagmatite molecule." The Stenzelberg mineral, analyzed by Rammelsberg,§ also approximates to it; but these three and the Dungannon hornblende are the only ones yet examined, so far as we are aware, that give at all closely the syntagmatite ratios. The following table gives the analyses of these four minerals and the molecular ratios deducible from them:

	Jan Mayen.	Molec. R.		Bohemia.	Mol. R.		Stenzelberg.	Mol. R.		Dungannon.	Mol. R.	
SiO_2	39·167	653	653	39·66	661	672	39·62	660	662	34·184	570	589
TiO_2	----	----		0·89	11		0·19	2		1·527	19	
Al_2O_3	14·370	140	218	14·83	145	222	14·92	146	210	11·517	113	192
Fe_2O_3	12·423	78		12·37	77		10·28	64		12·621	79	
FeO	5·856	81		1·97	27		7·67	106		21·979	305	
MnO	1·505	21		-- --	--		0·24	3		0·629	9	
MgO	10·521	263		14·25	356		11·32	283		1·353	34	
CaO	11·183	200	648	12·74	227	663	12·65	226	685	9·867	176	620
K_2O	2·013	21		1·25	13		2·18	23		2·286	24	
Na_2O	2·478	40		2·47	40		1·12	18		3·290	53	
H_2O	·396	22		----	--		0·48	26		0·348	19	
	99·912			100·43			100·67			99·601		

In all four analyses the ratios for $(R_2O+RO) : R_2O_3 : SiO_2$ (including TiO_2 when present) are practically 3 : 1 : 3, or, to give the exact figures (excluding water):

	(R_2O+RO)	:	R_2O_3	:	SiO_2
Jan Mayen	2·87	:	1	:	2·99
Bohemia	2·99	:	1	:	3·02
Stenzelberg	3·14	:	1	:	3·15
Dungannon	3·12	:	1	:	3·07

The ratio $(R_2O+CaO) : (Mg, Mn, Fe)O$ is, as observed by Scharizer in the case of the Jan Mayen and Bohemian hornblendes, approximately 3 : 4, thus:

* N. Jahrb. f. Min., 1884, ii, p. 143.
† loc. cit.
‡ Min. Mitth., iv, 23, 1881.
§ Pogg. Ann., 1858, ciii, 454.

	Including Water.			Excluding Water.		
	(R_2O+CaO)	:	(Mg, Mn, Fe)O.	(R_2O+CaO)	:	(Mg, Mn, Fe)O.
Jan Mayen	3	:	3·87	3	:	4·17
Bohemia	3	:	4·10	3	:	4·10
Stenzelberg	3	:	4·02	3	:	4·38
Dungannon	3	:	3·84	3	:	4·11

Scharizer adopts the foregoing ratios (3 : 1 : 3 and 3 : 4) as those of syntagmatite in calculating the composition of hornblendes intermediate between $(\overset{I}{R}_2\overset{II}{R})_3\ \overset{III}{R}_2Si_3O_{12}$ and actinolite. He assumes in the first place that all the alumina and ferric oxide belong to the syntagmatite molecule (Σ). The sum of the Al_2O_3 and Fe_2O_3 molecules (from the molecular ratio) multipled by *three*, gives $(SiO_2)\Sigma$ on the one hand and $(R_2O+RO)\Sigma$ on the other. The sum of $(R_2O+RO)\Sigma$ divided in the proportion of 3 : 4 gives $(R_2O+CaO)\Sigma$ and $MgO+FeO)\Sigma$. Subtracting $(MgO+FeO)\Sigma$ from the sum of the corresponding molecules deduced from the analysis gives $(MgO+FeO)_A$—that is the number of molecules of magnesia and ferrous oxide belonging to the actinolite molecule (A)—and $(MgO+FeO)_A$ divided by three (see actinolite formula) gives the lime molecules of the actinolite $(CaO)_A$. This value subtracted from the total number of lime molecules gives $(CaO)\Sigma$, and $(CaO)\Sigma$ subtracted from $(R_2O+CaO)\Sigma$ gives the alkali molecules (in some cases including H_2O). Finally $(MgO+CaO)_A$ gives $(SiO_2)_A$. These statements will be made clearer by the following example, one of those selected by Scharizer.

HORNBLENDE FROM EDENVILLE, ANALYZED BY RAMMELSBERG.

Original analysis.		Molec. R. deduced from analysis.	Syntagmatite.		Actinolite.	Calculated composition.	Original analysis calc. to 100.
SiO_2	51·67	861	222		609	51·97	52·66
Al_2O_3	5·75	56	56	74	---	5·99	5·86
Fe_2O_3	2·86	18	18		---	3·00	2·91
MgO	23·37	584	127		457	24·35	23·82
CaO	12·42	222	70		152	12·96	12·66
Na_2O	0·75	12	12	222	- -	0·78	0·78
K_2O	0·84	9	9		---	0·88	9·86
H_2O	0·46	25	4		---	0·07	0·47
	98·12					100·00	100·00

Here $(SiO_2)\Sigma = 3(56+18) = 222$

$(R_2O+RO)\Sigma = 3(56+18) = 222$

$$(R_2O+CaO)\,\Sigma = 3\frac{(R_2O+RO)}{7}\Sigma = \frac{222\times 3}{7} = 95$$

$$(MgO)\Sigma = 4\frac{(R_2O+RO)}{7}\,\Sigma = \frac{222\times 4}{7} = 127$$

$(MgO)_A = 584-(MgO)\Sigma = 584-127 = 457$

$$(CaO)_A = \frac{(MgO)_A}{3} = \frac{457}{3} = 152$$

$(CaO)\Sigma = 222-(CaO)_A = 222-152 = 70$

$(Na_2O+K_2O+H_2O)\Sigma = (R_2O+CaO)\Sigma-(CaO)\Sigma = 95-70 = 25$

But $(Na_2O+K_2O)\Sigma = 12+9 = 21$

$\therefore (H_2O)\Sigma = 4$

Finally $(SiO_2)_A = (MgO+CaO)_A = 457+152 = 609$

Having thus deduced the molecular ratios of the syntagmatite and actinolite, the numbers for each constituent are multiplied by the corresponding molecular weights, in order to obtain the theoretical relative weights of the constituents of the mixed hornblende.

Syntagmatite.		Actinolite.	
222×60	$= 13320$	609×60	$= 36540$
$56\times 102{\cdot}6$	$= 5745$	----	----
18×160	$= 2880$	----	----
127×40	$= 5080$	457×40	$= 18280$
70×56	$= 3920$	152×56	$= 8512$
12×62	$= 744$	----	----
9×94	$= 846$	----	----
4×18	$= 72$	----	----
	32607		63332

Then,

$$(32607+63332):(13320+36540)::100:x$$

and $x = 51{\cdot}97$ = p. c. of SiO_2 in the mixed hornblende. And in like manner the percentages of the other constituents are calculated.

But 32607 : 63332 practically as 1 : 2, and therefore the formula of the Edenville hornblende might be regarded as

$$\overset{II}{R}_3\overset{III}{R}_2Si_3O_{12}+2(Mg_3CaSi_4O_{12})$$

or as Scharizer gives it

$$10(\overset{II}{R}_3\overset{III}{R}_2Si_3O_{12})+20(Mg_2CaSi_4O_{12})$$

The analyses selected by Scharizer agree remarkably well with his theory, but there are aluminous hornblendes whose constitution cannot be readily explained in this way and which at the same time cannot be referred to the pargasite orthosilicate.*

Garnet.—In the hand specimens the garnet is seen to possess a deep reddish-brown color. In the thin sections it is a paler brown although still deeply colored. It is not found in all parts of the mass and where it does occur is usually present only in small amount. It possesses the usual high index of refraction and is quite isotropic, occurring usually in irregular shaped grains but in some few cases showing distinct crystalline form. It frequently holds a few large inclusions which usually consist of calcite in single individuals, although the garnet is perfectly fresh and the calcite shows no distinct evidence of a secondary origin. It moreover sometimes holds inclusions of the hornblende above described, of pyrite, iron ore and even of nepheline. A garnet resembling this occurs in small amount associated with a similar hornblende, as above mentioned, in the nepheline-syenite of the Corporation Quarry at Montreal, and it also contains as inclusions most of the other constituents of the rock. The same is also true of the melanite in the nepheline-syenite of Alnö.†

Before analysis the garnet was purified by several separations with fused silver nitrate and on careful examination with the microscope the grains appeared to be entirely free from foreign matter. With the pycnometer their specific gravity at 16° C. was found to be 3·739. Chemical analysis gave the following results:

Silica	36·604
Titanium dioxide	1·078
Alumina	9·771
Ferric oxide	15·996
Ferrous oxide	3·852
Manganous oxide	1·301
Lime	29·306
Magnesia	1·384
Loss on ignition	·285
	99·577

The atomic and quantivalent ratios deduced from the above analysis are as follows:

* See Scharizer's paper, loc. cit., p. 156.

† "Ueber das Nephelinsyenitgebiet auf der Insel Alnö," von A. G. Högbom. Geol. Fören. i. Stockholm Förh., 1895, p. 144.

	Atomic.		Quantivalent.	
Si	610×4 =	2440	2492	2492
Ti	13×4 =	52		
Al	192×3 =	576	1176	2466
Fe^{III}	200×3 =	600		
Fe^{II}	53×2 =	106	1290	
Mn	18×2 =	36		
Ca	523×2 =	1046		
Mg	35×2 =	70		
H	32	32		

The ratio for $RO : R_2O_3 : (SiTi)O_2$ is 629 : 196 : 623, or, calculating the titanium as Ti_2O_3, 629 : 203 : 610 = 3 : 1 : 3. The analysis therefore accords well with the ordinary garnet formula $3RO, R_2O_3, 3SiO_2$ or $\overset{II}{R_3}\overset{III}{R_2}Si_3O_{12}$, and the mineral may be regarded as a titaniferous andradite, with a considerable proportion of the ferric oxide replaced by alumina. In composition it resembles somewhat the brown garnet from the Island of Stokö, analyzed by Lindström.*

By way of comparison the analysis of the Stokö garnet and also one of a garnet from the nepheline-syenite of the Island of Alnö† are included in the following table.

	Stokö.	Molec. R.		Alnö.	Molec. R.		Dungannon.	Molec. R.	
SiO_2	36·63	610	610	31·15	519	603	36·604	610	623
TiO_2	----	---	---	6·73	84		1·078	13	
Al_2O_3	9·97	98	182	3·14	31	180	9·771	96	196
Fe_2O_3	13·45	84		23·83	180		15·996	100	
FeO	2·28	32	698	----	---	616	3·852	53	645
MnO	·63	9		·58	8		1·301	18	
CaO	35·90	641		33·44	597		29·306	523	
MgO	·28	7		----	---		1·384	35	
Na_2O	---	---		·68	11		----	---	
Ign.	·16	9					·285	16	
	99·30			99·55			99·577		

* Zeitschr. fur Kryst. u. Min., xvi, 160, 1890.

† Sahlbom, in the paper by Högbom already cited.

Art. XXIII.—*Proofs of the Rising of the Land around Hudson Bay;* by Robert Bell, of the Geological Survey of Canada.

[Read before the Geological Society of America, Philadelphia, 27th December, 1895. Abstract.]

In the provinces of Ontario and Quebec, it has been found from actual levellings by Gilbert, Spencer and Upham, that the old shore-lines are not perfectly horizontal, but that they slope upward in a northeasterly direction at rates varying in different regions from a few inches to a foot and even two feet per mile. If this upward slope were continued in the same direction to the northeastern extremity of Labrador, 1300 miles from Lake Huron, the increase in the elevation might there amount to 1000 or 2000 feet. It is scarcely probable that the differential elevation is constant and regular for such a great distance. Still, it is a fact that well preserved shore-lines are to be seen at great heights in the northern parts of Labrador. In my Geological Survey Report for 1884, I have mentioned ancient beaches at Nachvak, 140 miles south of Hudson Strait, which have an estimated altitude of 1500 feet above the sea.

The two sides of Hudson Bay present very different physical characters. The eastern is formed mostly of crystalline rocks and, as a rule, is more or less elevated, with a broken surface sloping somewhat rapidly westward or towards the bay; while the western side is mostly very low and much of it is underlaid by nearly horizontal Silurian and Devonian strata. These low shores are accompanied by shallow water extending far to seaward. The head of James Bay, which forms the southern prolongation of Hudson Bay, is extremely shallow, but the various rivers which flow into it have cut channels through the soft shallows, and by means of these the land may be approached with sea-going vessels. The whole of Hudson Bay may be said to be shallow in proportion to its great area, as the soundings show that it does not average more than 70 fathoms in depth.

The shores of the bay everywhere afford abundant evidence that there has been a comparatively rapid rise in the land and that the elevation is still going on. I have mentioned numerous proofs of this in my various official reports on the geology of these regions from 1875 to 1886, and I shall now recall a few of those and give fresh ones in addition, some of which came to my knowledge on a journey to the bay during the past summer. It is well known to those who have paid any attention to the subject that since the establishment of the posts of

the Hudson's Bay Company in the mouths of the rivers around the bay, 200 years ago, there has been an ever-increasing difficulty in reaching these establishments from the sea.

On the eastern side the most striking evidence of the rising of the land is afforded by the numerous well-preserved and conspicuous terraces cut in the till and other deposits. Near the sea these may be seen at various heights, up to about 300 feet, but above this elevation the scarcity of soft material out of which terraces might be excavated, renders this kind of evidence less apparent than it might otherwise be, at higher levels.

On this side of the bay, one of the best evidences that the elevation of the land is still going on is furnished by the long lines of driftwood which one sees in many places far above the reach of the highest tides. The old beaches, on which this wood is plainly seen, occur at various levels up to about thirty feet above high tide, but the remains of rotten wood may be detected in some localities up to nearly fifty feet, above which it has disappeared from the ancient shores by long exposure to the weather. This driftwood consists principally of spruce, but a little white cedar and other kinds, which have been brought down by the rivers, are also mixed with it. The bark having been worn off by the action of the waves while the trunks were still fresh, has tended to their preservation. Owing principally to the salt water and the cold climate, wood endures for an incredibly long time in exposed situations in this region wherever it has an opportunity of drying quickly after rain. Some of the wood which may still be seen upon the higher levels may be upwards of 600 years old.

It has been suggested that all this driftwood along hundreds of miles of coast may have been thrown up by some extraordinarily high tide. But there are many reasons why this is quite unlikely. It seems impossible that any modern tide could rise to such a great height and deposit so much wood at different levels all at once and in such even lines, following all the sinuosities of more than one of the raised beaches. The supposititious extraordinary tide would necessarily be of brief duration and would be accompanied by a tremendous gale blowing upon the coast. This would have the effect of throwing the wood in confused heaps and only into situations favorable for catching it, such as angles of the shore. But instead of this, we find it at different levels laid longitudinally all along, as if accumulated by slow degrees with moderate winds from every quarter. The fact that the wood is freshest along the lower lines and becomes progressively more and more decayed as we ascend, and that finally only traces remain on the higher levels, shows that it must have been stranded from time to time as the land was rising above the sea, and we are forced to adopt this obvious view of the case.

In support of the paroxysmal tide theory, it is related that once during a northern gale the tide was forced as high as the front gate in the palisaded enclosure at Rupert House near the head of James Bay, and it is added that this would be equivalent to a height of about thirty feet. When at Rupert House last summer, I could hear no authentic account of such an extraordinary rise in the water and besides the gate referred to did not appear to be more than fifteen feet above the sea-level. But even if such a great rise in the water had once occurred at this place, it would prove nothing in regard to the raised beaches on the long straight shore out on the open sea. Hudson Bay is about 1000 miles long and its outline is funnel-shaped, with James Bay representing the contracted extremity. Rupert House is situated near the end of this narrow continuation, so that just here we should expect very high water with a spring tide and northern gales driving the sea in from the broad expanse outside and heaping it up at the extremity of the constantly narrowing termination.

The gravel terraces seen at various elevations around the coves and upon the thousands of small islands along the east coast of James Bay are remarkably sharp and well-preserved and almost as fresh-looking as if they had been formed but yesterday. They are generally bare of trees or bushes and the yet smooth surface-pebbles are only partially covered by lichens. Similar terraces may be seen farther north on this coast and in Hudson Strait, wherever material exists out of which they may be formed. On Marble Island the raised beaches are very plainly visible on account of the whiteness of their smooth, quartzite shingle.

On the west side of Hudson Bay the land is generally too low to admit of the relatively higher sea-levels of former times having been recorded in the shape of terraces near the present shore line, but if we go back into the woods we shall find unmistakable evidence of the existence of such higher levels at comparatively recent periods. These consist of long, low ridges of drifted materials, such as we see in a fresher state at the present high tide mark. They are made up of driftwood and other vegetable debris in a completely decayed condition, covered by moss and having trees and shrubs growing upon them. In some places we may still trace the forms of the larger trunks which had been cast ashore by the waves at high tide. Between these ridges and the present shore there is a thick growth of the coniferous forest and the ground is carpeted with moss, over which the tide has never passed. Examples of these low ridges may be seen near the head of tide-water at the mouth of Nelson River, at Attawapishkat River and in places between the latter and Albany River.

To the west and southwest of James Bay the till, covering the nearly flat Silurian and Devonian rocks, is generally overspread by stratified clays. Marine shells are found in these up to an elevation of 400 to 500 feet, but on the eastern side of the bay no fossils have yet been detected at such high levels, owing perhaps to the scarcity there of marine deposits and to the fact that but little search has yet been made for them. In the sandy deposits among the hills about twenty miles south of Cape Wolstenholme, I saw abundance of *Saxicava rugosa* and *Tellina Grœnlandica* with smaller numbers of a few other species, at heights varying from the sea level up to about 200 feet; and last summer I found brackish water varieties of a number of the commoner species of our northern marine shells up to 70 feet above the sea in the clay banks along the lower portion of the Noddawai River.

Around the head of James Bay and up its western side the encroachment of the outer lines of the forest upon the wide alluvial flats which extend all along these shores and are constantly broadening towards the sea is good evidence that a rising of the land is now going on. The existing condition in this part of the bay is well described by Mr. A. P. Low in speaking of Agoomski Island. On page 24 J. Geol. Survey Report for 1887, he says:

"The island closely resembles the adjoining mainland in physical character, being very low and swampy. The shore-line above high-water mark is made up of muddy flats covered in part with grasses and sedges, followed further inland by thick growths of small willows, these in turn giving place to small black spruce and tamarac as slightly higher ground is reached. The line of these trees is often over two miles inland from high-water mark, itself a long distance from the sea at low water."

No living mollusks are to be found in James Bay except perhaps in the northern part, owing probably to the muddy and brackish nature of the water, but abundance of the dead shells of a considerable number of kinds are washed out of the clays forming the present shores. Some of these belong to moderately deep-water species and are well-preserved, retaining the epidermis. This, of course, shows a recent elevation of the sea bottom.

Richmond Gulf on the eastern side is separated from the main bay by a high bar of stratified rocks, which strike with its length and dip westward or towards the open sea. This bar is cut through by several gaps, all resembling one another, except in their heights above the sea, and all bearing evidence of their having been well worn channels of communication at more or less remote times according to the greater or less eleva-

tion of their beds above the sea. Only one narrow passage now remains open or low enough to admit the water, but two others are as yet only slightly raised above the tides.

Some of the aboriginal geographical names around the head of James Bay are significant of considerable changes in the topography since these shores became inhabited by the natives who still occupy them. The large peninsula between Hannah and Rupert bays is called Ministik-oo-watum, which means wooded island with a cove or hole in it, ministik being the Cree for a wooded island and watum for a cove or hole. The heads of the channels, which now run in behind the present peninsula from the opposite sides, are separated by a strip of low ground some ten miles long covered by bushes. Midway across this strip, the elevation is estimated to be about fifteen feet above high tide. The most prominent point on the coast between Moose Factory and Fort Albany is now called "Cockispenny" by the whites, but the Cree name is Ka-ka-ki-sippin-a-wayo Minis, or Island where the Crow-duck (Cormorant) lays eggs. Since this island became connected with the mainland, bushes have taken the place of the grasses and sedges which first grew upon the low ground between them, and the former are constantly acquiring a stronger growth. Many years ago the winter trail of the coast passed over the neck of this peninsula, but now it has become necessary to go outside of it, because the bushes have grown so large that they catch the snow which, in such situations, remains too soft for dog teams and snow-shoers.

The salt marshes along the west coast of James Bay and also in the vicinity of York Factory, which used to attract vast numbers of wild geese and ducks, have been gradually drying up, much to the inconvenience of the Hudson's Bay Company's people, who depended largely upon them for food.

The character of the lower portions of such rivers as the Moose, Albany and Attawapishkat shows a recession of the sea. This is particularly observable in the lower thirty miles of the Moose, where very long and narrow or ribbon-like islands run parallel to one another for many miles. The process of their formation appears to have been a constant drawing out of their lower extremities as the sea receded from them, just as the lowest islands of the present day are growing.

On the east-main coast, where the land is comparatively high, the grade of the rivers is rapid as they approach the bay, and in some of them, as the Nastapoka and the Langlands, there are perpendicular falls of about 100 feet almost directly into the sea. This condition indicates recent elevation.

One of the best evidences of the modern rising of the land is to be found in the beach-dwellings of the Eskimos, which

may be seen at all elevations up to about 70 feet. In summer these people generally camp on the shore, and their favorite locations are at the mouths of small streams into which the sea trout run at high tide. Here they construct weirs of stones, which impound the fish when the tide retires. On Outer Digges Island, I have found these fish traps and the rings of stones and other structures marking their old camping places, up to a height estimated at 70 feet.

Among the historical evidences bearing upon this question since the advent of the white man, may be mentioned the fact that in 1610, Henry Hudson, the navigator, wintered in a bay full of islands on the east coast south of latitude 53°. None of the bays in this region would now be possible for this purpose, showing that a considerable change in the level of the sea has taken place in less than 300 years.

In 1674, Charles Bayley, then local governor for the Hudson's Bay Company, sailed through in a sloop between Agoomski Island and the main west shore of James Bay. It would now be impossible to pass here in a sea-going vessel of any kind. In 1886 I found it difficult to get through in bark canoes, drawing only a few inches of water. The shoaling is not due to a silting up, since the almost dry bottom consists of a level surface of till with bowlders scattered thickly over it.

From 1675 to 1685 the Hudson's Bay Company's establishment in the mouth of Moose River was upon Hayes' Island, which, it is to be presumed, was selected for convenience of landing goods from their vessels and shipping out their returns. This island is now unapproachable except by canoes and small boats. For more than 200 years the factory* has stood upon Moose Island, the next below Hayes' Island. The annual ship from England anchors in the channel cut through the sands off the mouth of Moose River. On account of the risk of rough water, it is necessary to discharge the cargo by schooners. Within the memory of living men, these schooners could ascend to a wharf built opposite the large storehouse of the factory. But for many years, the same schooners have been unable to ascend all the way, and the cargo requires to be transferred into scows, which complete the trip to the wharf; and the distance to which the schooners can ascend is constantly diminishing. In the beginning of the present century Princess Island, a narrow bushy strip immediately in front of the factory, was separated by a channel with a good depth of water at the lowest tides. Last autumn I saw it quite dry on several occasions during ebb tide. It is well known to every one who has lived at this post in the present generation that every now and then a new "lump" will appear in the bed of the river

* Factory, a residence of a factor or agent.

and become permanent, growing higher and higher, eventually escaping submergence at most tides and at length becoming covered with grass and then with bushes. Some islands which were covered only with bushes forty or fifty years ago, now support a growth of young trees. The small one on the west side of Middleboro', below Moose Island, is an example of this and the appearance of the trees upon it is within the memory of Mr. Broughton, the gentleman now in charge of Moose Factory. Middleton Island, between the mouths of Rupert and Noddawai rivers, lies close to the east shore of Rupert Bay. Up to a few years ago, canoes and boats could pass at high tide through the long narrow grassy channel behind this island, but last autumn I found it impossible to do so with my canoes and we were obliged, at great inconvenience, to go round outside.

Two hundred years ago, the ships of the Hudson's Bay Company appear to have had no difficulty in entering the mouths of various rivers on the Eastmain coast which cannot now be used as harbors. In old times the principal post of the company on that coast was in the mouth of Eastmain River, which had no doubt been chosen because it afforded a good harbor. It is only a few years since the mouth of Little Whale River, several hundred miles farther north, had to be abandoned as a harbor on account of the increasing shallowness of the water.

At York Factory there is a "ship hole" in the channel of Hayes' River, directly in front of the storehouse. The sea-going vessels of light draft employed in the Hudson's Bay Company's trade have been accustomed to anchor in this hole and formerly they remained afloat at all stages of the tide, but of late years, vessels drawing even less than those of former times have begun to "take the ground" at low water. In objection to the belief that the land is rising it may be said this may be due to a silting up of the hole, but on examining the material brought up on the flukes of the anchors, I found it to consist of light colored stiff bowlder clay or till.

In 1782, after the French Admiral Lepeyrouse had destroyed Fort Prince of Wales at the mouth of Churchill River, he landed with cannons on the southeast side of Nelson River and hauling them across the point between it and Hayes' River, captured York Factory. Two ships belonging to the Hudson's Bay Company which were then lying in Hayes' River, laden with valuable cargoes, escaped under cover of the darkness of the following night and got safely to England. At the present time, it is only possible for a sea-going vessel to get out from this river at the top of high water with favorable wind and careful piloting in daylight. To say nothing of the difficulty

caused by the darkness, it is unlikely that all the other conditions now necessary to enable a vessel to leave the river, conspired to aid the escape of these ships. It is much more reasonable to believe that the water was deeper then than it is now. The landing of Lepeyrouse with his guns on the shore of Nelson River abreast of York Factory was a feat the like of which could not be accomplished at the present day, owing to the extreme shallowness of the water.

The present Fort Churchill or "New-Fort," as it is still called, was built in 1782 on the west side of the river about four miles and a half above Fort Prince of Wales as soon as the French had retired after destroying the latter establishment. The residents now suffer much inconvenience on account of the continued shoaling of the water and they have been obliged to lengthen out their "launch" or long landing tressel from time to time in order to be able to reach the outer end of it with their coast boats.

Off the western side of the lagoon within the mouth of Churchill River is Sloop's Cove, a small elliptical pond connecting with the lagoon by a very narrow entrance, through which the water barely passes at high tide. On the arkose rocks beside this little cove many inscriptions have been cut and some ring-bolts have been fastened, for mooring vessels, all of which indicate that the cove was used for wintering ships in old times. Indeed it is known that the "Furnace" and the "Discovery," two small ships commanded by Captain Middleton, passed the winter of 1741–42 in this cove. I have examined the place on various occasions and have copied most of the sketches and inscriptions on the rocks, and it always appeared to me that the conditions which we observe indicate a rise in the land since the last ship wintered there. At the present time, the tide does not rise high enough to allow of the passage into it of crafts larger than ordinary row-boats. No sea-going vessel could now enter it, which would indicate an elevation nearly equal to the draft of the ships formerly frequenting it. It would be a boon to the agents of the Hudson's Bay Company at Churchill if they could now winter their small schooner in this cove instead of being obliged to send her every autumn to winter at York Factory. The captain who commands her happens to be the person now in charge of the company's post at Churchill, and both he and his crew are obliged to walk back 150 miles through the mud from York Factory after leaving their vessel there in the autumn and to walk the same distance again to bring her back in the spring. Mr. J. B. Tyrrell visited Sloop's Cove in the autumn of 1893, and in a paper published in the Geological Magazine for August, 1894, says he thinks the land is here in a state of equi-

librium. Two inscriptions which he saw on the rocks, namely, "May 25th and May 27th, 1753," were about seven feet above the present high tide and he thinks these were cut by men standing on the ice. This, however, does not prove much, for the men were quite as likely to have sat as stood while engraving these inscriptions. As the tide still enters the cove and keeps it full of water, the average relative level of its ice to the rocks surrounding it may not have differed much from what it is now. When I visited Fort Prince of Wales in 1879, oak planks brought from England while the fort was still occupied as well as timbers of native wood, all charred by Lepeyrouse's fire, were found stranded far out of reach of the present tides and still in perfect preservation. On the occasion referred to, I met at the "New Fort" children of some of the people who were living at the "Old Fort" when it was captured by the French, and from them some information could be obtained as to the conditions at that time. We have, besides, the description and illustrations in the book by Samuel Hearne, who was then in charge of the place. Any light which these accounts may throw on the state of matters then as compared with the present time, points in the direction of some elevation having taken place.

Among the photographs which I took around Fort Prince of Wales in 1879 is one which shows strips of dry land grasses alternating with little parallel ridges of gravel thrown up by the waves and now above the highest tide-mark, but *below* the level of the spot which was pointed out to me as the landing place of Lepeyrouse. The ground on which the fort stands was an island during high tide at the time the place was occupied and a bridge was thrown across the narrowest part of the little separating channel to connect the island with the main land. This channel is now entirely dry.

If anything further were wanting to show that an elevation of the land is now going on in this region we have some direct personal evidence in the lifetime of the witness himself in support of the facts already cited. About twenty years ago, a very aged Indian, who was said to have "seen more than a hundred winters," and who was quietly passing the last years of his extraordinarily long life at Norway House, told me in presence of the factor, Mr. Roderick Ross, and the other gentlemen of that establishment that he had, when a boy, witnessed the landing of Lepeyrouse and the destruction of Fort Prince of Wales. He gave graphic details of every circumstance, which agreed perfectly with Lepeyrouse's own account, and he answered all my questions on other points entirely satisfactorily and without a moment's hesitation. Among other things, he mentioned that the spot where the Frenchmen's boats landed was quite

close to that portion of the western wall which they undermined and blew up with gunpowder. He said that when all was ready, they laid "a rope" (train) of gunpowder across the beach and setting fire to the end of it, ran off to a safe distance to witness the effect. It is now a considerable distance from this spot to the nearest point of water at high tide.

The proofs of the rising of the land around Hudson Bay in post-glacial times would be admitted by any geologist, and the question of the continuance of the movement at the present time is, I think, answered in the affirmative by the actual general shoaling of the water which is going on and the encroachment of the land on all sides, some proofs of which have been given in the foregoing pages. All the facts which have been mentioned (and many more might be added) point in the same direction, while there appears to be no evidence of a contrary character. The officers of the Hudson's Bay Company are an intelligent set of men, and their universal opinion, based upon lifetimes of observation, is that the land all around the bay is rising. The following is part of a letter recently received from Mr. Joseph Fortescue, lately a chief factor in the Hudson's Bay Company, in answer to my request for his opinion on this subject:

"Regarding the rising of the shores of Hudson Bay, I have no doubt whatever. When I was at York Factory, I heard several Indians say that the sea or tide had retired two miles from places they remembered when they were young, and my own observations during twenty years there would lead me to entertain the same opinion. When I revisited Moose Factory, after nearly forty years absence, I found a great change in the appearance of the coast and river. Channels which were navigable at all times of the tide formerly, could now only be used at high water."

ART. XXIV.—*On the Occurrence of Thaumasite at West Paterson, New Jersey;* by S. L. PENFIELD and J. H. PRATT.

IN 1878 Baron von Nordenskiöld* described a mineral from the copper mines of Åreskuta, Jemtland, Sweden, which, according to the analyses of Lindström,† had the composition $CaSiO_3$, $CaCO_3$, $CaSO_4$, $14H_2O$ and to which the name thaumasite was given, from *θαυμάζειν, to be surprised.* The mineral was not found in distinct crystals but was crystalline and on a fracture showed a fine fibrous structure. Its homogeneous character and its right to be considered a distinct mineral species rested upon the following: The material seemed to be homogeneous when examined with the microscope, and the three analyses of Lindström, made upon material collected in the early part of this century by Polheimer, in 1859 by Nordenskiöld, and in 1878 by Engberg, agreed not only very closely with one another but also with the theory demanded by the formula.

That a mineral with such a remarkable composition was capable of existence was not accepted by all mineralogists, and Bertrand,‡ on examining thin sections of it with the microscope was led to believe that it was a mixture, composed of a uniaxial mineral with negative double refraction supposed to be calcite, of a biaxial mineral gypsum, and of a third mineral, the optical properties of which could not be made out, probably calcium silicate or wollastonite.

The idea of Bertrand's that thaumasite was a mixture was not accepted by Nordenskiöld, and the latter to sustain his position presented the following arguments,§ which were very convincing: First, if it were possibly a mixture it certainly would be very remarkable that three independent samples, collected at such widely separated periods, should agree so closely in percentage composition. Second, there is no known hydrated calcium silicate which, when mixed with calcite and gypsum, could yield a product containing over 42 per cent of water. Third, it would not be possible for a mixture of calcite, gypsum and wollastonite, with specific gravities of 2·72, 2·31 and 2·90 respectively, to yield a product with such a low specific gravity as thaumasite, 1·877.

Specimens were moreover sent to Lacroix for renewed

* Comptes Rendus, vol. lxxxvii, p 313, 1878.
† Öfv. Ak. Stockholm, vol. xxxv, No. 9, p 43, 1878.
‡ Bull. Soc. Min. de France, vol. iii, p. 159, 1880, and vol. iv, p. 8, 1881.
§ Geol. För. Förhandl., Stockholm, vol. v, p. 270, 1880.

optical examination, and in a letter to Nordenskiöld he states* that the material was found to be practically homogeneous, uniaxial and with negative double refraction, but whether hexagonal or tetragonal could not be determined. The uniaxial material which Bertrand had taken for calcite was in reality thaumasite, and Bertrand in a letter to Nordenskiöld† withdrew his objection. He gives also the approximate indices of refraction $\omega=1{\cdot}503$, $\varepsilon=1{\cdot}467$, which differ from those of calcite.

In 1890 Widman‡ described specimens of thaumasite belonging to the mineral collection of the University of Upsala, which are reported to have been found at Kjölland, about thirteen miles from the original locality Åreskuta, and two analyses by Hedström quoted by him agree very closely with the ones made by Lindström. From Hedström's analyses the formula $CaSiO_3$, $CaCO_3$, $CaSO_4$, $15H_2O$ was derived, and as pointed out by Widman this slight change in the formula agrees satisfactorily with the analytical results of Lindström, who really had found over fourteen and one-half molecules of water.

It is with pleasure that the authors are able to announce the discovery of this unusually interesting mineral at Burger's quarry, West Paterson, New Jersey, the material having been first brought to our notice by Mr. Geo. L. English, of New York, who sent a specimen of it to the mineralogical laboratory of the Sheffield Scientific School for identification. The mineral occurs as an aggregate of prismatic crystals, sometimes so loosely held together that the individuals can be separated by crushing between the fingers, while more often the masses are firm and have somewhat the appearance of white alabaster. Occasionally distinct prismatic crystals were observed, averaging $0{\cdot}5^{mm}$ in diameter and 2 to 4^{mm} in length, but they were poorly formed and without distinct terminations. Some of the masses showing fine prismatic crystals have a decidedly silky luster. There is a distinct prismatic cleavage. Measurements were only possible in the prismatic zone and approximated to 60°, which determine the crystallization as hexagonal. On examining fragments imbedded in Canada balsam ones can readily be found which show a uniaxial interference figure with negative double refraction. Using a polished plate, the index of refraction for the ordinary ray was determined by means of total reflection in α-mono-bromnaphthalene and found to be 1·5125 for yellow Na. By means of a prism of 32° 58′ the following values were also obtained for yellow, $\omega=1{\cdot}519$

* Geol. För. Förhandl., Stockholm, vol. ix, p. 35, 1887.
† Ibid., vol. ix, p. 131, 1887.
‡ Ibid., vol. xii, p. 20, 1890.

and $\varepsilon=1{\cdot}476$. It must be stated, however, that a prism cut from a crystalline aggregate cannot yield wholly satisfactory results, as the light does not traverse a single individual, and that for example which yielded the extraordinary value above was vibrating in crystals whose vertical axes were approximately and not perfectly parallel to the edge of the prism. Levy and Lacroix* give $\omega=1{\cdot}507$ and $\varepsilon=1{\cdot}468$.

In order to be absolutely sure of the uniform character of the material for analysis, selected pieces of the mineral were crushed and sifted to a uniform grain and separated by means of methyl iodide CH_3I, which was diluted with ether. That every particle of the mineral in the separator floated at a specific gravity of 1·887 and sank at 1·875, a difference of only 0·012, is sufficient proof of the homogeneous character and great purity of the material. Lindström gives as the specific gravity of the Swedish mineral 1·877 and Widman gives 1·83.

The results of the analysis are as follows:

	I.	II.	III.	Average.		Ratio.
SiO_2	9·23	9·33	9·23	9·26	·155	·97
CO_2	6·87	6·77		6·82	·155	·97
SO_3	13·56	13·32		13·44	·168	1·05
CaO		27·08	27·19	27·13	·484	3·04
H_2O	42·81	42·72		42·77	2·377	15·00
Na_2O	·39			·39		
K_2O	·18			·18		
				99·99		

The ratio of $SiO_2 : CO_2 : SO_3 : CaO : H_2O$ is very nearly $1:1:1:3:15$, demanded by the formula $CaSiO_3$, $CaCO_3$, $CaSO_4$, $15H_2O$. The analytical results are, moreover, very close to those obtained upon the Swedish mineral by Lindström and Hedström. A slight amount of alkali sulphate is probably present as impurity, therefore the alkalies have been neglected in making the above calculation. That Na_2O and K_2O are not isomorphous with CaO is shown by the following experiment: 1·1765 gram of the powdered mineral were treated in a platinum dish for over two days with cold water, the insoluble mineral was then filtered off and the soluble portion analyzed, with the following results: SiO_2, 0·39 per cent; SO_3, 0·56; CaO, 0·56; Na_2O+K_2O, 0·25. These indicate that thaumasite is slightly soluble and that the alkalies have an independent existence, for a quantity of Na_2O+K_2O equal to about one-half of that found in the original analysis was

* Les Minéraux des Roches, p. 286, 1888.

extracted, while relatively only a very small proportion of the calcium was dissolved, a result which would not have taken place if the alkalies had belonged with the thaumasite. A small quantity of alkali sulphate may, therefore, be regarded as impurity, and deducting from the analysis the alkalies and sufficient SO_3 (0·64 per cent) to convert them into sulphates, and recalculating to one hundred per cent, the following results are obtained, which agree satisfactorily with the values required by theory:

	By recalculation.	Theory.
SiO_2	9·38	9·64
CO_2	6·90	7·08
SO_3	12·95	12·86
CaO	27·47	27·01
H_2O	43·30	43·41
	100·00	100·00

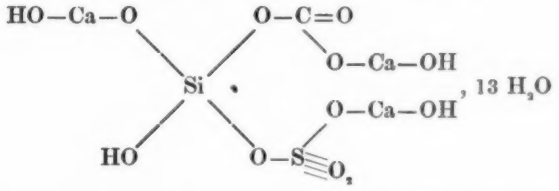
Hoping to obtain data concerning the constitution of the mineral, experiments were made to determine the temperature at which the water was driven off. As determined by Lindström, the mineral slowly loses water at 100° C., and in our experiment, after heating for over ninety hours, a loss of 29·35 per cent was obtained, but the weight had not become constant. At 150° the weight soon became constant and then at 200°, 250° and 300° respectively constant weights were obtained, and in each case the heating was continued until the loss of weight during several hours did not amount to more than a few tenths of a milligram. Between 300° and 360° no loss of weight was obtained, but the material still contained water which, as seen by a closed tube experiment, was expelled at much below a red heat.

The results obtained from ·6663 grams of the air-dry mineral are as follows:

	Loss.	Proportional parts using $\frac{1}{12}$ of total H_2O as unity.
Two days in dessicator	Nothing	
Nine hours at 150°	37·41	13·13
Seven hours at 200°	1·82	0·64
Eight hours at 250°	1·41	0·50
Five hours at 300°	1·05	0·37
Below redness	1·08	0·38
Total	42·77	

It is evident from the above that 13 molecules are to be regarded as water of crystallization and two molecules, suffi-

cient to form four hydroxyls, as constitutional. The last two molecules are, moreover, expelled at four separate temperatures, indicating the existence of four hydroxyls which play different parts or have different positions in the molecular structure. It is evident also that the $CaSiO_3$, $CaCO_3$ and $CaSO_4$, together with the water, are united in some way into a complex molecule, and probably as suggested by Groth* in some way analogous to the combination of silicate and sulphate in the haüyne-nosean group of minerals or of silicate and carbonate in cancrinite. Regarding silica as the linking non-metallic element, the following constitution may be suggested as a probable one:



The above may also be expressed as $[(CaOH)CO_3]$ $[(CaOH)SO_4]$ $[CaOH]$ $HSiO_3$, 13 H_2O. The formula agrees in a very satisfactory manner with the results obtained in driving out the water, for it demands four independent and different hydroxyl molecules.

Formulæ may be written with four hydroxyls and with either carbon or sulphur as the linking element, but they do not seem to the authors so probable as the one given above.

The occurrence of thaumasite at Paterson is in the trap which has been quarried for road material. It is associated with heulandite, apophyllite, laumontite, pectolite, chabazite, scolecite and natrolite, all of which are found at the locality in beautiful crystals. Widman mentions the occurrence of apophyllite with the thaumasite at Kjölland. The thaumasite has crystallized later than the zeolites and occurs upon or surrounding them. A considerable quantity of it was found.

In closing the authors express their thanks to Messrs. Geo. L. English & Co. of New York for generously furnishing them with material for the investigation.

Mineralogical-Petrographical Laboratory,
Sheffield Scientific School, February, 1896.

* Tabellarische Uebersicht der Mineralien, p. 149, 1889.

ART. XXV.—*The Age of the Wealden;* by O. C. MARSH.

THE Wealden formation of England has long been studied, and is now well known in nearly all its features. Its stratigraphical relations and its Cretaceous age are usually regarded as fully determined, and this is true, also, of the corresponding strata on the Continent.

The vertebrate fauna of the Wealden is of special interest, and has attracted much attention ever since Mantell in 1825 unearthed *Iguanodon* in the Tilgate Forest. Some of the remains, he sent, through his friend, Professor Silliman, to Yale College, where they have proved of much service. In 1865, the writer examined the same famous locality, as well as others on the south coast of England especially rich in vertebrate fossils, and at all of them secured interesting specimens. A study of these in connection with the collections at London and Brussels first made the writer question the Cretaceous age of the Wealden, and a later comparison of its reptilian fauna with allied forms found in the Rocky Mountains led him to the conclusion that both series were Jurassic in type, and should be placed in that division of the geological series.

At the meeting of the British Association, at Ipswich, in September last, the writer read a paper on European Dinosaurs, including two from the Wealden, and thus the question of their geological age came up for determination. The facts presented by the writer, based mainly upon the reptilian fauna, strongly indicated the Jurassic age of the Wealden, and he urged a re-examination of the question by English geologists.* The subject has since been taken up by Smith Woodward, with special reference to the fossil fishes. In the Geological Magazine for February, 1896, he gives the main results of his investigation, which prove that the fishes, also, of the Wealden are of Jurassic types, thus placing the geological age of this formation beyond reasonable doubt. The concluding statement of this interesting article is as follows:

"The Wealden estuary seems to have been the last refuge of the Jurassic marine fish-fauna in this part of the world, not invaded even by stragglers from the dominant race of higher fishes which characterized all the seas of the Cretaceous period. The Wealden river drained a land where a typically Jurassic flora flourished; the only two known Mammalian teeth from the Wealden resemble those of a Purbeckian genus; and now it is clear that the fishes agree both with these and the reptiles in their alliance with the life of the Jurassic era."

Yale University, February 22d, 1896.

* Report, British Association for the Advancement of Science, p. 688, 1895; and this Journal, vol. l, p. 412, November, 1895.

ART. XXVI.—*Experiments upon the Cathode Rays and their Effects;* by ARTHUR W. WRIGHT. With Plates VI–VII.

THE history of the investigations which have led to our present knowledge of the phenomena of electrical discharges in rarified gases, and especially of the actions which take place at the negative electrode in an exhausted tube, is a long one and full of interest. But while there are many memoirs of very high importance, those which most immediately relate to the subject here considered are two papers of Philipp Lenard, of the University of Bonn,* which marked a great advance in the study of the cathode rays, and the paper of Professor W. C. Röntgen,† of Würzburg, which has attracted immediate attention from the novelty and importance of the results therein announced.

In his first paper Lenard, by a series of very ingeniously contrived experiments, showed how, by the use of a small window of thin aluminium, the cathode rays could be obtained in the air outside of the vacuum-tube, and their properties studied by the use of fluorescent screens and of sensitized photographic plates. He showed that they could be traced to a distance of several centimeters in air, that they penetrated various materials in different degrees, determined in a large measure, by the circumstances under which they are originated. He proved that in air and other gases they undergo a lateral diffusion or scattering, as if by the action of a turbid medium, and this in different amounts depending upon the degree of exhaustion of the tube in which they originated. His researches led him to the conclusion that the cathode rays are phenomena of the ether. Among many experiments may be cited one in which he obtained a photographic picture, in an opaque metallic box, one side of which was made of thin aluminium. In his second paper he studies the relative absorption of the rays by different materials, showing that, broadly, the absorption is proportional to the density of the matter, and independent of its kind, but that the order of the different kinds of matter in this respect is to some extent dependent upon the character of the rays.

Prof. Röntgen's paper, which is full of most interesting results, greatly extends the range of the phenomena observed, especially as to the remarkable power of the rays to penetrate masses of matter, and brings up some very important questions as to their character. He states that as obtained outside of the vacuum-tube they are not deflected by a magnet to an appreciable extent, that they undergo neither refraction, reflec-

* Wied. Ann., li, p. 225, 1894; lvi, p. 255, 1895.

† Sitzungsberichte der Würzburger Physik-medic. Gesellschaft, 1895; translation in Nature, vol. liii, p. 274, Jan. 23, 1896.

tion nor polarization, that they do not produce perceptible heating effects, nor influence the magnetic needle. These characteristics differentiate them strongly from luminous rays, and he suggests, but with great moderation in statement, that they may be longitudinal waves in the ether. To these questions of high scientific importance, were added descriptions of results obtained in the production of photographic pictures of objects through considerable masses of matter opaque to light, thus revealing the inner structure of bodies otherwise invisible, and even showing, in the body of an animal, the bones clearly distinguished from the flesh.

These results were of such great interest that physicists were immediately incited to test their reality, and to witness the novel effects. The present paper gives an account of experiments made by the writer in the Sloane Physical Laboratory of Yale University, and, omitting many details, follows the general course of the work as it was carried out.

For the production of the cathode rays, a Crookes' tube, nearly spherical in shape, was used, of the kind often employed to exhibit the independence of the negative electrode in high vacua. It is provided with four electrodes, three of straight wire, of which two are situated at the opposite extremities of a diameter and directed radially, while the third is placed at the end of a diameter at right angles to the line of the other two. The fourth is situated a little to one side of the point opposite the third electrode just described. This disposition is advantageous, as it leaves a space of smooth thin glass opposite the third and fourth electrodes, which were the ones employed, sometimes one, sometimes the other, as the cathode. The fourth wire terminates in a slightly concave disk or cup about two centimeters in diameter. The concave disk concentrates the cathode rays, issuing normally from its surface, at a point near the opposite surface of the tube, sending them through a small area of the glass wall, which becomes strongly heated. The photographic plates show this concentration of the rays plainly. On account of the unequal distribution of the effect, however, as well as because of the inferior definition of the pictures thus obtained, the third straight wire electrode was used in preference. This gave somewhat less intense effects, making a longer exposure necessary, but the results were otherwise much more satisfactory. The induction coil used with the tube gives a spark of six or seven centimeters in air, and was actuated by four, sometimes five, secondary cells.

The first photograph obtained with this apparatus, on Jan. 27, was made upon a piece of bromide paper which had been wrapped in thick black paper. It gave very clear representations of the objects employed. In the evening of the same

day a strong picture was made upon a photographic dry-plate covered with a thin, white-wood board. In some of the earlier experiments the objects to be tested were separated from the sensitive plate by a screen of wood from a centimeter to a centimeter and a half in thickness. Strong effects were produced easily, but the pictures had a blurred appearance, which was largely due to the increased distance from the plate, but in part also to the diffusing or scattering effect of the wood. Later, an ordinary photographic plate-holder was used, the objects being simply laid upon the ebonite slide, the vacuum-tube being supported directly over it at a distance of from four to six inches. In general it may be said that the pictures have the appearance of shadows, and the conditions which are necessary for the production of distinct shadows by ordinary light apply to them, especially the greater distance of the radiating source, and nearness of the object to the surface upon which it is to be projected. To secure the latter condition the best arrangement was simply to wrap the photographic plate in one or two thicknesses of black opaque paper, as a protection from ordinary light, and to lay the objects upon this. Increasing the distance of the vacuum-tube improved the pictures in the matter of sharpness, fulness of detail, and accuracy of form and dimensions, but the time of exposure was correspondingly increased. In one experiment a variety of objects was selected to test the action of the rays upon different materials. On one side of the plate were arranged four equilateral prisms, two of flint glass, one of Faraday's heavy glass, and one of quartz. Two of these were drawn out of line with the other two, so that a straight steel wire laid along them was met by the sloping surfaces from opposite sides. It was hoped that the trace of the wire upon the plate would show the presence or absence of refraction, as it was so placed that the trace would be displaced in opposite directions by alternate prisms in case of refraction. Unfortunately the prisms proved too opaque to the rays to show the desired effect. The quartz transmitted a little at the thin edges, the flint glass prisms very little, and the heavy glass still less. A block of calcite proved also to resist the passage of the rays very strongly, and where some passed through the thin edges, there was no trace of duplication of the images, showing the absence of double refraction and polarization. A metallic mirror set so as to throw a trail of rays along the plate in case of regular reflection showed no such effect whatever, nor did the polished surfaces of the prisms and of the Iceland spar. The plate showed, however, that a scattering of the rays occurred at various points where they encountered the surfaces of the objects, and this effect was noticed on many other occasions in the different experiments.

This confirms the statement of Prof. Röntgen that regular reflection does not occur, and the theoretical results announced by Jaumann in his remarkable paper, where he shows that diffuse reflection may occur but not specular reflection.* Other objects upon this plate were slips of differently colored glass, ebonite, tin-foil and thin sheet aluminium. The latter having a thickness of about $0{\cdot}1^{mm}$, transmitted the rays so freely that it shows but very faintly upon the negative, and not at all upon the prints from it. The ebonite $1{\cdot}8^{mm}$ in thickness ranked next in permeability. The slips of glass (crown) showed apparently no effect dependent upon color, the effect in stopping the rays being evidently dependent chiefly upon the thickness. The tin-foil transmitted the rays somewhat freely, and the impression shows the various little irregularities in its surface. Lead a little more than a millimeter thick was practically opaque.

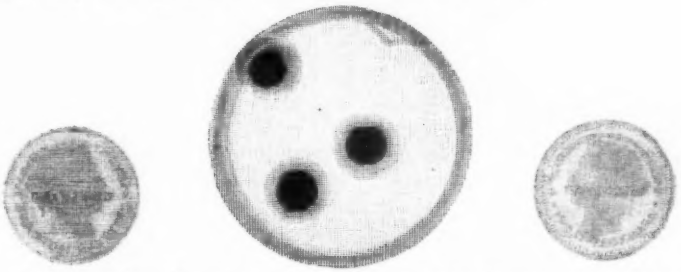
Other experiments were made upon the bodies of animals and the human hand. A rabbit, purchased in one of the markets of the city, after an exposure of one hour to the rays, left upon the plate a complete representation of the bony skeleton, the bones of the legs being very sharply and perfectly represented. The region of the lungs was more transparent than the rest of the body, and the heart still more so, being somewhat definitely outlined. The cartilages at the base of the ears left a distinct trace, the ears themselves scarcely any. Particularly interesting in this photograph were several small round spots which appeared dark in the positive print. These were at once surmised to be shot, and from the indication of their location in the print were readily found and extracted. The mode of death of the animal was not previously known. Similar results were obtained with the body of a rat, the whole skeleton being shown, with some of the tendons. Organs of the abdominal region were also discriminated to some extent.

The photograph of the hand shows the bones and their articulations very clearly and well defined. On the side of each finger the plexus of nerves and blood-vessels is distinctly shown as it divides into several branches for distribution to the ball of the finger. When the negative is held to the light the hand appears as if modeled in a translucent, luminous material, with the full appearance of roundness and solidity. It is as if it had become nearly transparent, so that the structure of the interior could be seen, not only in respect to the particulars already mentioned, but also with respect to the distribution, or relative abundance, of the blood in its different parts. It may be remarked here that this effect is noticed in many other cases. The pictures are not merely flat shadows, but the partial opac-

* Longitudinales Licht., Wied. Ann., lvii, p. 147, 1895.

ity, varying with the thickness, gives a corresponding depth of shade in the picture, thus producing an effect of perspective, which in the negative, or a negative transparency projected upon a screen, has a striking effect of relief, and a luminous solidity often of great beauty.

As in the case of tissues which are rather freely traversed by the rays the differences of shade in the impression are not very great, the development of the negative requires especial care. It is better to use a developer of less than the ordinary strength, and to use no alkaline accelerator at all, until just at the end of the process, and then very sparingly and chiefly for the purpose of intensifying the picture. This makes the process very long and tedious, but the results amply compensate for the labor of obtaining them. Aside from this it appears that the photographic plates which have been subjected to the rays are peculiarly slow, even with the ordinary mode of development. The picture is a long time in making its appearance and grows very gradually. This is perhaps in part due to the fact that the effect of the cathode rays extends through the entire thickness of the film, which must therefore be thoroughly developed to the bottom to bring out the full effect, or possibly to a specific action upon the film itself.

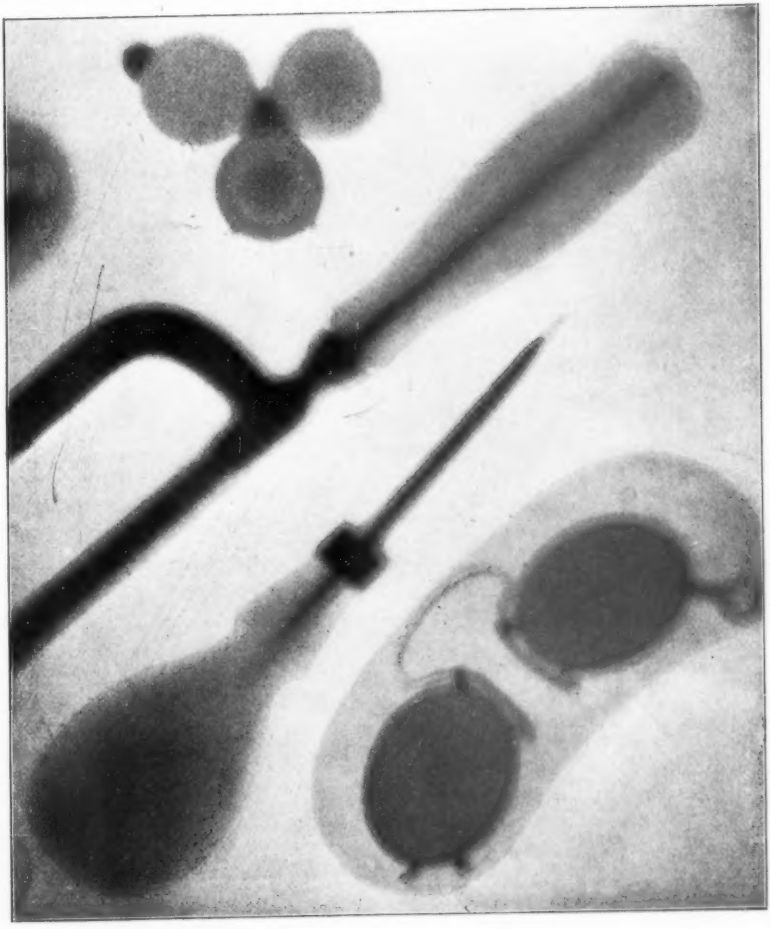


The results of some of the many experiments are shown in the accompanying cut, and in Plate VI. These are selected, not so much for any special interest in the objects themselves, as for the reason that they illustrate some of the characteristic features of the pictures obtained by the use of Prof. Röntgen's method. The cut, from a plate made January 30, shows a small paper box filled with cotton in which were imbedded three metallic spheres, which had been used in the laboratory as pendulums. The sphere nearest the edge was aluminium, the one nearest the center platinum, the other brass. They were all of the same size. The cover of the box was in place during the exposure. The box and its cotton filling show little hindrance to the passage of the rays, only the vertical walls showing, with an inward nick where the

side was crumpled by the tight cover. The aluminium sphere appears diminished in size by the passage of the rays more freely through the lesser thickness of its periphery, and leaves a lighter trace upon the plate than the two others, which are practically opaque, and nearly alike. On either side of the box was a medal of aluminium, the head in one being uppermost, in the other beneath, the two being alike except in position. The medal is one made by Johnson Matthey & Co., some years ago, and one side, the reverse, bears the name of the firm, and the address, HATTON GARDEN, around the rim. Across the middle of the face is the word REFINERS. On the obverse is the bust of Queen Victoria, and around the rim the words VICTORIA QUEEN. The raised rim is serrated on the inside on the obverse, but is plain on the reverse. In the cathode picture, owing to the great permeability of the metal, the designs and letters upon both sides are shown, appearing as a similar medal in translucent wax would, if viewed by transmitted light. In the negative the separate letters can be distinguished, and two dots separating the name from the address, though the letters are hardly clear enough to enable one unacquainted with their import to make out the inscriptions. The gradations of light and shade in the negative are too delicate to be represented adequately in any process print, but are fairly well shown in the wood-cut. The position of each medal can be determined from the greater distinctness of that side which was nearest the photographic plate.

The plate, VI, represents a portion of a picture obtained Feb. 1. The handles of the saw and awl are of cherry wood. This appears very transparent, but gives a shading proportional to the thickness of the wood. The tang of the awl is clearly seen, and that of the saw also, extending entirely through the wooden handle, and expanded or riveted at the end to prevent it from being pulled out in use. The eye-glasses in their leathern case show minute details of form, and the varying thickness of the lenses is indicated by corresponding depth of shade. The same effect is shown still more strikingly by the figure of the pocket lens in its ebonite mounting, where no effect of refraction can be traced, the lenses simply showing the greater thickness at the center by the deeper shading. The sides of thin ebonite are separated by thicker pieces of the same material at the ends, and are held together by two brass rivets which are plainly depicted.

With a view to study the character of the rays outside of the vacuum-tube the following experiments were made: A flat, rectangular plate of copper, $1{\cdot}8^{mm}$ in thickness, $25{\cdot}5^{cm}$ long, and $21{\cdot}5^{cm}$ wide was used, and in the center of this two straight, parallel slits $1{\cdot}5^{mm}$ wide and 35^{mm} long were cut



Scale, two-thirds.

2. 1. 3.

Scale, two-thirds.

through the metal. Their inner edges were 5·6^{mm} apart, and they were parallel to the shorter dimension of the plate. On one side of the copper plate was soldered a strip of thinner sheet copper at right angles to the length of the slits, and about three millimeters from their ends. One side of the strip was turned up at right angles to the copper plate and formed a ledge for the end of the sensitive plate to rest upon, and to serve as a guide in placing it in position. The copper plate was placed in a horizontal position beneath the vacuum-tube and distant from it about one decimeter (97^{mm}), the cathode being carefully brought directly above the slits and pointing towards them. In the first experiment, the results of which are illustrated in Pl. VII, the distance of the nearest part of the tube was greater, being 132^{mm}. The sensitized photographic plate, wrapped in a single thickness of black paper, was placed beneath the copper plate, with its upper end resting against the guide ledge at the inner end of the slits, and inclined at such an angle that its lower end was beyond the vertical line through the outer end of the slits. The streams of cathode rays passing through the slits were thus intercepted by the dry plate, upon which they left their trace throughout its length. The experiment was carried out as follows:—The dry-plate was first placed so that the slits were at the middle of its upper edge. One of the slits was covered with a strip of thick copper plate and an exposure of 30 minutes made, after which it was uncovered, the copper strip transferred to the other slit, and a second exposure of equal length made. This was for the purpose of fixing upon the plate the position of the cathode stream from each slit uninfluenced by the presence of the other. The sensitive plate was now moved along in its own plane, both slits were uncovered, and a new exposure of the same length as before was made. This was to detect any repulsion such as occurs under similar circumstances within a vacuum-tube. Finally the photographic plate was moved in the opposite direction, bringing the slits over a point nearly midway between the center and the edge, and a powerful Jamin magnet so placed, that if any effect upon the cathode streams were produced, such as is seen in a vacuum-tube, they would be deflected away from the center of the plate. The consecutive positions of the slits relatively to the plate are indicated by the numbers 1, 2, 3 in the illustration, Pl. VII.

Development of this plate showed some interesting results. Opposite each position of a slit is a trail extending nearly across the length of the plate, of the same breadth as the slit where the latter met the upper end of the plate, and spreading out in a fan like shape at an angle of very nearly 15°. The sides of each trail, near the origin, are well defined, and recti-

linear, or nearly so, but at a distance of a centimeter, or a little more, from it, they show an outward curvature, which increases with the distance, and their edges become blurred and diffuse, like the rays shown in Lenard's first paper, already quoted, but in a much less degree. Traces of curvature produced by the magnet, appear to be faintly indicated, but if real are very slight. Mutual repulsion of the two streams produced simultaneously appears to be shown, but the effect is very little. To the eye the three pairs of streams appear to be nearly alike, and even a careful measurement of the angular dimensions of the trails shows but a minute difference, too small to be made the basis for any positive conclusion.

Within the tube the cathode rays are accompanied by metallic matter derived from the substance of the electrode, and the minute portions of the metal, whether in the form of vapor or fine dust, have been shown by various investigators to be negatively electrified. The electrostatic repulsion of these would be a cause for the mutual repulsion of two cathode streams, as shown in a well-known form of Crookes' tube, while the motion of the electrified masses, causing them to act like an electrical current, as was proved by Rowland,* would render them susceptible to magnetic attractions or repulsions. This also is a familiar observation in respect to cathode streams. Now the glass walls of the tube do not suffer the metallic matter to pass through them, and the metal is deposited upon them, in the form of a sooty coating, or under proper condition, of a mirror-like film of brilliant luster.† Naturally, then, the rays outside of the tube being freed from the metallic matter would show the effect of mutual repulsion and magnetic deviation in a less degree, or not at all. If, however, it were possible to make them pass through a metal which would be volatilized by them to some extent, the effects might be expected to reappear.

To test this point the previous experiment was repeated with this modification: The slits were covered with two layers of ordinary gold leaf, thin enough to transmit light readily, two being used to lessen the chance of small rifts permitting the rays to pass unimpeded and to interfere with the result. To compensate for the lessened effect of the rays, caused by the gold leaf, the vacuum-tube was brought a little nearer the slit-plate, to a distance of 97^{mm}. Otherwise the arrangement and adjustment were exactly as before, and the exposures were made in the same manner, but were slightly longer, 40 minutes each. Gold was selected for this experiment for the reason that it had been found, in earlier experiments by the writer,‡

* This Journal, III, xii, p. 390, 1876; xv, p. 30, 1878.
† This Journal, III, vol. xiii, Jan. 1876, p. 49; vol. xiv, Sept. 1877, p. 169.
‡ This Journal, loc. cit.

to be volatilized with great facility when used as a cathode. It was thought that the passage of the cathode rays through it would cause the liberation of the metal in their path, in the same manner as within the tube, and thus cause them again to become susceptible to mutual repulsion, and to deviation by a magnet.

This expectation appeared to be justified by the character of the trails upon the developed photographic plate, although the changes were not great. The angles were determined by measurement, in most cases by pricking the outlines of the streams with a fine needle on a positive print, and then tracing the lines of direction of the perforations with a straight-edge upon paper. The angular spread of the streams was greater than in the previous experiment, being now about 18°. The effect of the magnet was shown by a small deviation, in the direction expected. The measurements of its amount were difficult to make, but all agreed in showing a positive effect, of something like half a degree. The mutual repulsion of the two streams was also clearly shown, the angle between the axes of the pencils being increased a little more than half a degree. It was also evidenced by the fact that when the axes were prolonged they were found to meet at a point nearer the slits than those of the pencils produced singly.

A third experiment, in which a sheet of aluminium, 0·26^{mm} in thickness, replaced the gold leaf, was now made under the same conditions as before. As this metal, though readily permeable by the cathode rays, is very slightly affected when used as an electrode, it was not to be expected that it would modify the stream of cathode rays to the same extent as the gold. This the developed plate confirmed. The magnetic deviation could not be detected with certainty, but the mutual repulsion of the two streams was somewhat greater than before.

An attempt to discover the point of departure of the rays was made by tracing the axes of the trails or pencils until they met upon the plot. In the case of the first two experiments, they were found to come together at a point very near the center of the spherical body of the vacuum-tube, thus indicating that they left the surface of the glass nearly normally. The third case showed the point of meeting nearer the cathode, but the results of the three pairs of pencils varied much from each other.

While it is doubtless premature, in the present state of our knowledge to formulate a conclusion as to the nature of the rays which produce these remarkable results, we may derive some useful suggestions from a consideration of the circumstances of their production. If the cause of the excitation is an ordinary induction coil, the resistance of the circuit of the secondary is so great that the oscillations in this circuit at each opening

or closing of the primary circuit will be rapidly extinguished, and the mode of discharge will approximate closely to a simple discharge at each movement of the interrupter, producing at the terminal of the electrode within the tube an unsymmetrical rise and fall of the electrostatic potential. This must give rise to the passage of inductive actions through the space surrounding the electrode both within and without the tube. The period or duration and phase of these inductive pulses will be essentially the same as those of the variations of potential at the surface of the electrode, and as these are not a continuous sequence like the elements of a train of waves, the inductive actions in space may be regarded as very probably occurring in the form of isolated or unsystematic pulses, succeeding one another at intervals long compared with their own duration, and more or less irregular with most forms of interrupters used with the coil, from the variations in their action. As to the mode of propagation of these pulses the most natural view would be to regard them as analogous to longitudinal compression waves in an elastic medium, but of an unsystematic character.

It may be of interest to recall the fact that appearances similar to these pictures produced by the rays from the cathode of a vacuum-tube, and not unlikely due to a similar cause, have been observed before. In a paper published by the writer in 1870,* it was shown that, under certain conditions, when the silent discharge took place between the terminals of a static electrical machine, a minute point-like brush appeared upon the negative terminal, and a glow upon the positive, in which appeared the figures of objects brought into the path of the discharge. When a piece of wire gauze was interposed, "the shadows were formed with striking distinctness. . . . Every peculiarity of texture was faithfully represented, the irregularities in the wires, breaks in the gauze, and the like, being accurately reproduced, and moving with the gauze, just as in the case of true optical shadows." In a subsequent paper† attention was called to the fact, that many cases of images formed upon the bodies of persons killed by lightning, which had been reported by reputable observers, might be explained by supposing that the objects represented were so situated as to interrupt the lines of electrical action. These facts suggest the probability that every electrical discharge, which is not simply a flow of potential along a conductor, may produce effects of a similar kind, though much inferior in accuracy of form and dimensions to those produced by the agency of the cathode rays from a high vacuum-tube.

Sloane Physical Laboratory, Yale University,
February 22, 1896.

* This Journal, II, vol. xlix, May, 1870, p. 381.
† Ibid., III, vol. i, June, 1871, p. 437. Also vol. x, Oct. 1875, p. 317.

Art. XXVII.—*Triangulation by means of the Cathode Photography;* by John Trowbridge.

Photography by means of the Röntgen rays seems already to be of great importance in examining certain portions of the human body to determine the presence of metallic bodies, calcareous formations, and fragments of glass. The shadow pictures as they are taken at present, however, do not give the approximate position of the shots, for instance, embedded in the flesh. They indicate only the line in which they are situated. It occurred to me that the principles of triangulation could be applied with success to determine more exactly the position of the metallic particles. I was led to this conclusion by considering Rumford's photometer. This instrument, it is well known, consists merely of a vertical rod placed opposite a suitable screen of white paper. The two lights, the intensities of which are to be compared, are placed in a fixed position, and throw two shadows of the rod on the screen. From a measurement of the positions of the lights when shadows of equal intensity are thrown on the screen, an extinction of the brightness of the lights can be obtained. Moreover, by measuring the distance between the shadows, and by drawing lines from them to the lights, the position of the rod throwing the shadows can be determined. This position is evidently at the intersection of these lines.

I have used two Crookes' tubes with two terminals making an angle with each other, and have employed a to-and-fro excitation by means of a Tesla coil. A suitable screen of glass shielded the sensitive plate first from one cathode and then from the other. From the distance between the shadow pictures of a shot, for instance, on the back of the hand and from the position of the terminals the height of the shot above the sensitive plate could be estimated. It seems to me that this method promises to be of importance in the surgery of the extremities of the body; for the question whether to make an incision from the palm of a child's hand or from the back of the hand is an important one. Stereoscopic pictures can also be obtained.

The use of a Tesla coil in obtaining shadow pictures is advantageous in certain respects, for by changing the size of the spark gap in the primary circuit of the Tesla coil one has a great range of electrical energy at command. This range can be still further increased by putting the spark gap in a magnetic field. I have taken such pictures in less than a minute, showing the bones in the fingers. The tubes were,

at first, destroyed by disruptive sparks over the surface of the tube which apparently penetrated the glass between the platinum terminals and the glass. I have lately discovered, however, that if the terminals of the tube are placed in a vessel filled with paraffine oil and if the oil is kept cool by an outside vessel filled with snow or ice, the entire energy developed by the Tesla coil can be employed, and the tubes are not destroyed.

I have tried wooden lenses, both double convex and double concave, in order to see whether the rays travel slower or faster in wood than in air, but my results are negative. A copper ring placed on a double convex lens of wood of approximately six inches focus, and one also on a concave lens of the same radius as the surfaces of the double convex lens, gave shadow pictures of the ring which were of the same size and character as those of an equal copper ring placed in air at the same distance from the sensitive plate.

We naturally turn to Maxwell's great treatise on Electricity and Magnetism, to see if a hint of this new phenomenon cannot be found there: for I believe there is no manifestation of electro-magnetism since the death of Maxwell which has not been predicted or treated by him in one form or another in his remarkable book. In section 792, vol. ii of the treatise on Electricity and Magnetism he says, "Hence the combined effect of the electrostatic and the electrokinetic stresses is a pressure equal to 2ρ in the direction of the propagation of the wave. Now 2ρ also expresses the whole energy in unit of volume. Hence in a medium in which waves are propagated there is a pressure in the direction normal to the waves, and numerically equal to the energy in unit of volume. Thus, if in strong sunlight the energy of the light which falls on one square foot is 83·4 foot-pounds per second, the mean energy in one cubic foot of sunlight is about 0·0000000882 of a foot-pound, and the mean pressure on a square foot is 0·0000000882 of a pound weight. A flat body exposed to sunlight would experience this pressure on its illuminated side only, and would therefore be repelled from the side on which light falls. It is probable that a much greater energy of radiation might be obtained by means of the concentrated rays of the electric lamp. Such rays falling on a thin metallic disc, delicately suspended in a vacuum, might perhaps produce an observable mechanical effect."

Jefferson Physical Laboratory.

ART. XXVIII.—*Notes of Observations on the Röntgen rays;* by HENRY A. ROWLAND, N. R. CARMICHAEL and L. J. BRIGGS.

THE discovery of Hertz some years since that the cathode rays penetrated some opaque bodies like aluminium, has opened up a wonderful field of research, which has now culminated in the discovery by Röntgen of still other rays having even more remarkable properties. We have confirmed, in many respects, the researches of the latter on these rays and have repeated his experiment in photographing through wood, aluminium, cardboard, hard rubber and even the larger part of a millimeter of sheet copper.

Some of these photographs have been indistinct, indicating a source of these rays of considerable extent, while others have been so sharp and clear cut that the shadow of a coin at the distance of 2^{cm} from the photographic plate has no penumbra whatever, but appears perfectly sharp even with a low power microscope.

So far as yet observed the rays proceed in straight lines and all efforts to deflect them by a strong magnet either within or without the tube have failed. Likewise prisms of wood and vulcanite have no action whatever so far as seen and, contrary to Röntgen, no trace of reflection from a steel mirror at a large angle of incidence could be observed. In this latter experiment the mirror was on the side of the photographic plate next to the source of the rays and not behind it as in Röntgen's method.

We have, in the short time we have been at work, principally devoted ourselves to finding the source of the rays. For this purpose one of our tubes made for showing that electricity will not pass through a vacuum, was found to give remarkable results. This tube had the aluminium poles within 1^{mm} of each other and had such a perfect vacuum that sparks generally preferred 10^{cm} in air to passage through the tube. By using potential enough, however, the discharge from an ordinary Ruhmkorff coil could be forced through. The resistance being so high the discharge was not oscillatory as in ordinary tubes but only went in one direction.

In this tube we demonstrated conclusively that the main source of the rays was a minute point on the *anode* nearest to the cathode. At times a minute point of light appeared at this point but not always.

Added to this source the whole of the *anode* gave out a few rays. From the cathode no rays whatever came, neither were

there any from the glass of the tube where the cathode rays struck it as Röntgen thought. This tube as a source of rays far exceeded all our other collection of Crookes' tubes and gave the plate a full exposure at 5 or 10^{cm} in about 5 or 10 minutes with a slow-acting coil giving only about 4 sparks per second.

The next most satisfactory tube had aluminium poles with ends about 3^{cm} apart. It was not straight but had three bulbs, the poles being in the end bulbs and the passage between them being rather wide. In this case the discharge was slightly oscillatory but more electricity went one way than the other. Here the source of rays was two points in the tube, a little on the cathode side of the narrow parts.

In the other tubes there seemed to be diffuse sources, probably due in part to the oscillatory discharge, but in no case did the cathode rays seem to have anything to do with the Röntgen rays. Judging from the first two most definite tubes the source of the rays seems to be more connected with the anode than the cathode, and in both of the tubes the rays came from where the discharge from the anode expanded itself toward the cathode, if we may roughly use such language.

As to what these rays are it is too early to even guess. That they and the cathode rays are destined to give us a far deeper insight into nature nobody can doubt.

Baltimore, Feb. 20, 1896.

SCIENTIFIC INTELLIGENCE.

I. Miscellaneous Scientific Intelligence.

1. *Longitudinal Light.* — The experiments of Lenard and Röntgen have awakened great interest in the question whether the cathode rays indicate a periodic movement in the direction of the propagation of the electro-magnetic waves sent out from the cathode. G. Jaumann states that he is the first to maintain that the manifestations of cathode rays support the hypothesis of longitudinal waves. He calculates that the order of magnitude of the time of swing of the cathode rays is from 10^{-8} to 10^{-9} seconds. E. Wiedemann, on the supposition that the cathode rays are a manifestation of ultra violet light, attributes to them a time of vibration of from 10^{-15} to 10^{-16} seconds. Lenard attributes to the rays wave lengths of the order of magnitude of molecules. Jaumann reviews the experimental evidence in favor of the hypothesis of longitudinal waves and finds it of great weight. He then turns to the equations which express Maxwell's electro-magnetic theory of light, and points out that the longitudinal wave, in the direction of the movement of the wave-point, is not expressed by these equations, and that they do not embrace the phenomena which are observed in rarified gases. On the supposition, however, that the dielectric constant and the magnetic permeability of the medium change in value during the instant of propagation, he is enabled to embrace in these equations the hypothesis of longitudinal waves. The paper is of much interest in view of the late development of the subject of cathode rays. —*Ann. der Physik und Chemie*, No. 1, 1896, pp. 147–148.

J. T.

2. *The Natural History of Aquatic Insects;* by L. C. Miall. (London and New York, 1895. Macmillan & Co.) — Professor Miall here gives us an excellent example of a kind of work too rarely seen, the popular and yet strictly scientific treatise on natural history. The short introductory chapter treats briefly of some essential matters relating to aquatic insects in general, such as the dominance of insects, their invasion of the waters, adaptation to aquatic conditions, the surface-film of water, etc. The rest of the book is devoted to descriptions of the structure, transformations, and habits of a series of typical species well apportioned among the different groups of insects. Although the species described are European, they are so closely related to North American forms that the work will serve as a guide for the American student almost as well as for the European. The numerous illustrations are excellent. S. I. S.

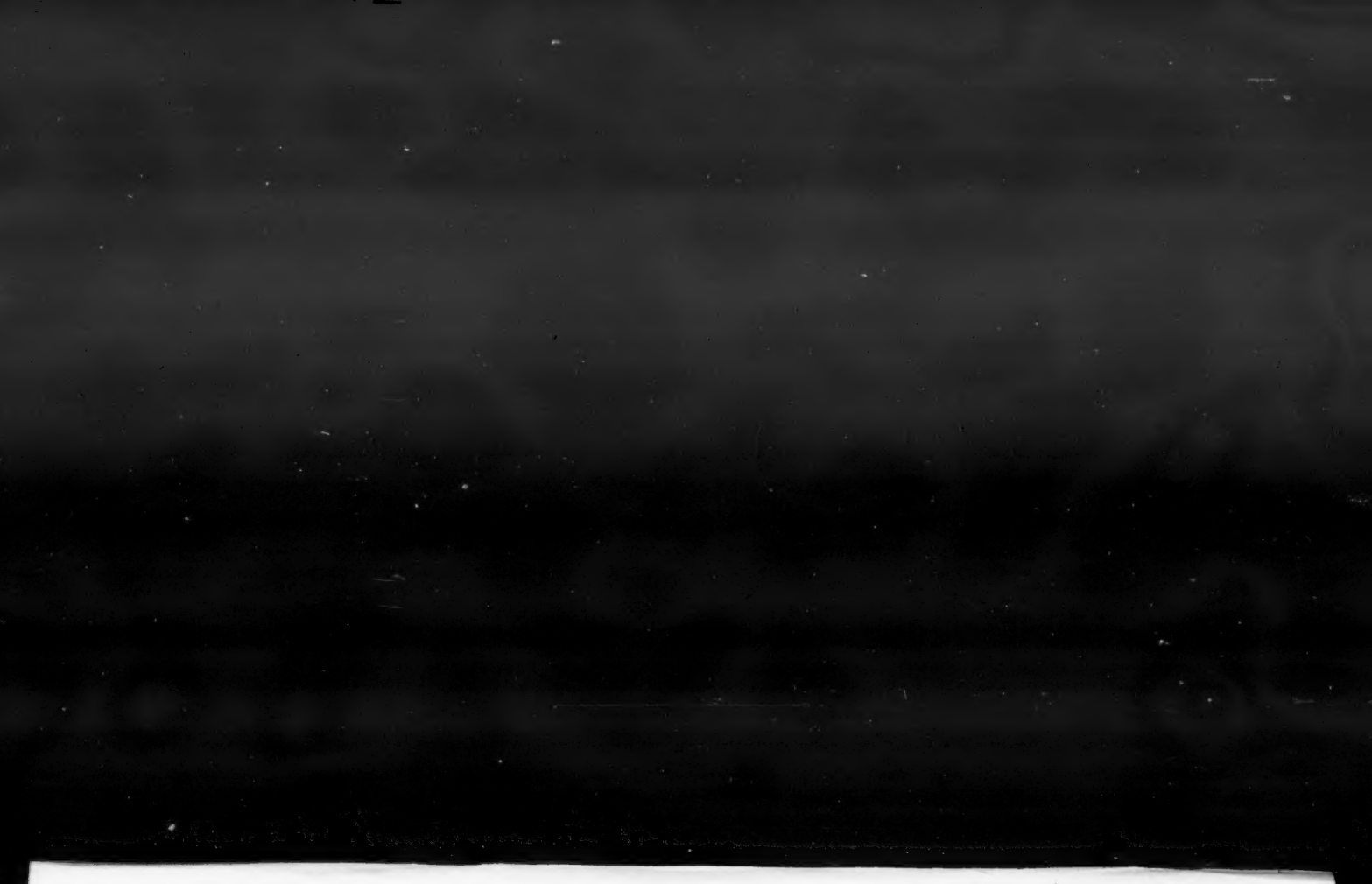
3. *Huxley Memorial.*—It is gratifying to learn that the movement to establish a permanent memorial to the late Professor Huxley has met with marked success. The committee announced in a circular dated Dec. 21, 1895, that the subscriptions up to

that time amounted to £1535. It is to be hoped that the scientific men of this country may not be backward in doing their share. Donations may be sent to the treasurer, Sir J. Lubbock, or the bankers, Messrs. Robarts, Lubbock & Co. (15 Lombard street, London, E. C.), or to the honorary secretary, Prof. G. B. Howes (Royal College of Science, South Kensington, S. W.). It has been decided that the memorial shall take the form of a statue, to be placed in the British Museum of Natural History, and a medal in connection with the Royal College of Science, and that the surplus be devoted to the furtherance of biological science in some manner to be hereafter determined by the committee, dependent upon the amount collected.

OBITUARY.

CHARLES WACHSMUTH died in Burlington, Iowa, on February 7th, aged sixty-seven. Dr. Wachsmuth has for many years been working on the classification of the fossil and recent Crinoidea and is well known to all paleontologists by the admirable "Revision of the Palæocrinoidea" prepared by himself and his constant friend and collaborateur, Mr. Frank Springer of Las Vegas, New Mexico. This work was issued in parts in the Proceedings of the Academy of Natural Sciences in Philadelphia; Part I appearing in 1879, Part II in 1881 and Part III, "A discussion of the Classification and relations of the Brachiate Crinoids and conclusion of the generic descriptions," in 1885 and 1886. At the time of his death the authors had in press an illustrated monograph on "The North American Fossil Crinoidea Camerata," which is being published by the Museum of Comparative Zoology, Cambridge, Mass. In a letter from Mr. Springer we are advised that all correspondence connected with the publication of this monograph should be addressed to Mr. Frank Springer, East Las Vegas, New Mexico, U. S. A.

ERRATA.

In the article by Prof. A. M. Mayer in the February number, 1896.

Page 83, line 13 from top, for 2·12 read 2·35.
Page 84, line 2 from top, for modulus increased, read modulus *at* 20° increased.
Page 84 and 85, for Keyser read *Kayser*.
Page 85, line 4 from bottom, for the vibrations read the *longitudinal* vibrations.
Page 93, line 14 from top, for 2135×10^6 read 2131×10^6.
Page 94, for moduls of glass at 40° read 748511034.
Page 94, under St. Gobain glass for 99·88, 99·76, 99·53, 99·30 read 99·76, 99·53, 99·30, 99·07
Page 103, line 22 from bottom, for renders read *render*.
Page 103, line 19 from bottom, for would have given read *gives*.
Page 103, line 12 from bottom, for equal intensity, read equal *initial* intensity.
Page 104, line 13 from bottom, for rest read *rests*.
Page 105, lines 19 and 21 from bottom, for from read *between*.
Page 105, line 17 from bottom, for Fig. 4 read *Figure* (3).